Volume 3 comments -- San Diego Count Water Authority

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Thank you for the opportunity to comment on Volume 3 of the public review draft of the 2013 State Water Plan Update. Our comments are in the form of sticky notes on the PDFs for chapters 3, 5, 8, 10, 12, 14, 20, 22 and 27. The San Diego County Water Authority has participated on a staff level in development of the Update, most notably through the Public Advisory Committee and as part of stakeholder groups both on a regional level and with specific topics such as the financing framework and several objectives and resource management strategies. We appreciated that DWR made these opportunities available and is open to meaningful stakeholder involvement.

We apologize for missing the Dec. 2 deadline for these comments and hope that you can still use them.

If you have any questions, please contact Mark Stadler, principal water resources specialist, at either mstadler@sdcwa.org or 858-522-6735.

Sent by Mark Stadler on behalf of Ken Weinberg, Water Resources Department Director

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Chapter 3. Urban Water Use Efficiency — Table of Contents

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Chapter 3. Urban Water Use Efficiency

Over the past few decades, Californians have made great progress in urban water use efficiency. Once viewed and invoked primarily as a temporary strategy in response to a drought or emergency water shortage situation, water use efficiency has become a permanent part of the long-term management of California's water supply. At the individual level, the benefits of water use efficiency may appear small, incremental, or difficult to see, but when Californians act together as a community to conserve water, the cumulative effect is significant, and the benefits are widespread.

There are several factors that have contributed to increased water use efficiency: outreach efforts that have increased awareness and changed behaviors; urban water suppliers' implementation of best management practices (BMPs); plumbing codes requiring more efficient fixtures; the Model Water Efficient Landscape Ordinance (MWELO); new technologies in the commercial, institutional, and industrial (CII) sectors; and mandates requiring that unmetered connections become metered.

However, with tighter environmental constraints on the Sacramento-San Joaquin River Delta (Delta), increasing population, and the necessity of adapting to climate change, even greater efficiencies will be needed and are achievable. When faced with an increasing demand for water, water agencies can consider options for increasing supplies or reducing demand, or a combination of both, to meet this need. Increasing water supply can be expensive and can include costs of purchasing additional water, capital cost of production and distribution systems, water supply treatment facilities, energy costs, and wastewater treatment facilities. Reducing demand through increased water use efficiency is generally lower cost and quicker to implement.

In an effort to emphasize and increase water use efficiency, the State Legislature has directed urban retail water suppliers to reduce urban per-capita water use by 20 percent by the year 2020. This legislation, the Water Conservation Act of 2009 (Senate Bill [SB] No. 7 of the 7th Extraordinary Session, or SB X7-7), was enacted as part of a five-bill package aimed at improving the reliability of California's water supply and restoring the ecological health of the Delta. SB X7-7 had multiple urban and agricultural water use efficiency provisions. The key urban conservation measure established a statewide goal of reducing urban per-capita water use by 20 percent by 2020. Meeting this statewide goal of a 20- percent decrease in demand will result in nearly a 2 million acre-foot (maf) reduction in urban water use in 2020.

This chapter will present the practices already employed in urban water conservation, as well as describing how further efficiencies can be achieved and how the goal of 20-percent reduction by 2020 can be met.

Urban Water Use Efficiency Today in California

Demand Management Measures and Best Management Practices

Demand management measures (DMMs) and best management practices (BMPs) are practices that can be used by urban water suppliers to conserve water, and the implementation of these practices has been a major driving force behind urban water conservation in California.

The Urban Water Management Planning Act placed the DMMs in the California Water Code (Sections 10610-10656) and required urban water suppliers serving more than 3,000 connections or more than 3,000 acre-feet (af) of water per year to describe their DMM implementation in their urban water management plans (UWMPs), which are required to be updated and submitted to the California Department of Water Resources (DWR) every five years.

These DMMs were included in the California Urban Water Conservation Council's (CUWCC's) memorandum of understanding (MOU). The CUWCC was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The council's goal is to integrate DMMs into the planning and management of California's water resources. When the DMMs were incorporated into the MOU, they were labeled as BMPs. Water agencies that became signatories to the MOU pledged to implement the BMPs to specified levels and to report progress on their BMP implementation biannually to the CUWCC.

Originally, the CUWCC BMPs were the same as the DMMs listed in the Urban Water Management Planning Act. But in 2008, the CUWCC BMPs underwent a significant revision. The BMPs were reorganized as either "Foundational" or "Programmatic" BMPs and were renumbered, as is reflected in Table 3-1. More details on the revised BMPs can be found at http://www.cuwcc.org.

The CUWCC BMP revision also provided member agencies three options for complying with the BMP water saving goals. The goals could be met through one of the following three measures:

- Performing the specific measures listed in each BMP.
- Performing a set of measures that achieves equal or greater water savings, referred to as the Flex Track Menu.
- Accomplishing set water savings goals as measured in gallons per capita per day (gpcd) consumption.

In order to be eligible for grant or loan funding from the State of California, an urban water supplier, whether a signatory to the CUWCC MOU or not, must demonstrate that its efforts in implementing each DMM or BMP will be implemented at the coverage level determined by the CUWCC MOU.

Some of the BMPs provide quantifiable water savings, and others do not. For example, within BMP 3 is the practice of toilet retrofits; replacing a 5-gallon-per-flush toilet with a 1.6-gallon-per-flush toilet yields water savings of 3.4 gallons per flush. Contrast that with BMP 2, "Education and Information Programs." Although education is critical to conservation and necessary to move people to new behaviors, it is not possible to correlate each educational effort with specific water savings.

PLACEHOLDER Table 3-1 Best Management Practices

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

20 x 2020: A New Direction

Box 3-1 describes the history, process, and impact of the *20x2020 Water Conservation Plan* (20x2020 Plan).

PLACEHOLDER Box 3-1 20x2020 Plan: History, Process, and Impact

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Baseline Water Use

The period used for baseline water use is roughly 1996 to 2005, though suppliers could choose any 10 consecutive years from between 1995 and 2010.

After compiling baseline water use from 342 water agencies, the statewide average baseline water use was calculated to be 198 gpcd (California Department of Water Resources 2012b).

Figure 3-1 shows how baseline water use differs regionally across the state, and Figure 3-2 displays the range of per-capita water use reported by the water agencies in their 2010 urban water management plans (UWMPs). Generally, lower water use is seen along the coast, with increasing water use in the inland valleys; however, low or high per-capita water use is not necessarily an indicator of efficiency. Climate and land use factors can have a significant effect on water use. The coastal areas generally use less water in their landscapes because the marine climate provides a lower rate of evapotranspiration and because the sizes of coastal residential landscapes tend to be smaller than those of inland areas. Increased efficiencies have also been needed on the coast, because these communities were strongly affected by the 1988-1992 drought and a number of conservation programs were implemented to improve water supply reliability.

PLACEHOLDER Figure 3-1 Average Baseline Water Use by Hydrologic Region

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 3-2 Range of Reported Baseline Water Use

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Baseline Water Use by Sector

The total volume of urban water use, statewide, as reported in *California Water Plan Update 2009* (Update 2009) is 8.8 million acre feet (maf) per year (California Department of Water Resources 2009). This is an eight-year average for the time period of 1998-2005. There is some variation in water use reporting between Update 2009 and the 20x2020 calculations used in UWMPs. When estimating urban water use, Update 2009 calculations included the use of recycled water, self-supplied industrial water, potable water supplied to agriculture, conveyance losses, and water used for groundwater recharge. The 20x2020 calculations used in UWMPs do not include these urban water uses.

Table 3-2 and Figure 3-3 show the division of the 8.8 maf of urban water use (California Department of Water Resources 2009) into water use sectors.

PLACEHOLDER Table 3-2 Statewide Urban Water Uses

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 3-3 Statewide Urban Water Use — Eight-Year Average 1998-2005

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Water Use in 2010 — Progress in Achieving 20-Percent Reduction by 2020

The 2010 statewide average water use, as reported in 2010 UWMPs, was xxxx [still being calculated].

Because of the economic downturn, the 2007-2009 drought, and a cool summer in 2010, many suppliers have reported significant drops in water use in the last few years, and some have already met their 2020 water use target. These suppliers are now focused on ways to keep water use low once the economy improves and a more typical weather pattern returns.

2015 and 2020 Water Use Targets

Water suppliers reported their 2015 and 2020 per-capita water use targets in their 2010 UWMPs. The average 2020 target reported was 166 gpcd. This target is a 16-percent reduction from the statewide average baseline of 198 gpcd, which is less than the 20-percent goal. The legislation provided four methods for calculating the 2020 target, and this allowed some suppliers to select targets lower than the 20-percent goal, but none of the methods require suppliers to select targets higher than 20 percent.

After receiving the 2015 UWMPs, DWR is required to report to the Legislature on progress toward the 20-percent reduction goal. Suppliers are expected to be halfway between the baseline and the 2020 target by 2015. If the state, overall, is not on track to meet the 20-percent target, DWR is directed to provide recommendations to the Legislature on how the goal can be achieved.

A list of the individual water supplier’s baselines and targets and more information on statewide and hydrologic region averages is available in DWR’s report to the Legislature on the 2010 UWMPs (California Department of Water Resources 2012b).

PLACEHOLDER Box 3-2 Demand Hardening

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Meeting the Targets — Potential Savings by Sector

Since the early 1990s, voluntary implementation of BMPs and new codes and regulations have increased water use efficiency in California. However, abundant opportunities still exist to increase urban water use efficiency, and many of these opportunities will need to be tapped in order for California to achieve its 20-percent reduction goal by 2020.

Descriptions of the potential for increased savings are presented below. These represent a statewide overview and are not intended as a blueprint for individual water agencies, because each agency will have its own unique strategy for achieving the 20-percent reduction.

All water savings noted in the following sections are comparisons to the baseline water use reported by water suppliers in their 2010 UWMPs. Because baselines and targets are reported in gpcd, the descriptions presented below will state the current water use and potential savings in gpcd.

Landscape Irrigation

Annual water demand for residential and large landscape irrigation amounts to approximately 4 maf, or about 45 percent, of urban demand. Because this sector represents such a large portion of urban water demand and because water waste from landscapes is common — water running down street gutters, leaks, watering during rainstorms, etc. — landscape irrigation presents the greatest opportunity for increasing efficiency and reducing unnecessary demand.

PLACEHOLDER Box 3-3 Landscape Irrigation Runoff

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Increased landscape water use efficiency can be accomplished with a variety of tools that are effective in any landscape sector, whether residential, commercial, or institutional. Some of these tools include regular maintenance of irrigation systems, irrigation audits to identify deficiencies, development of landscape water budgets, and selection of low-water-using plants. Some tools are low- or no-cost and can provide immediate and significant savings.

Urban landscapes can be divided into three categories: residential; large landscape; and commercial, institutional, and industrial (CII) mixed meter. Each of these uses is addressed more specifically below.

PLACEHOLDER Box 3-4 The Value of Landscape Water Budgets

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Residential Landscapes

Residential landscape irrigation represents the single largest end use of urban water, accounting for 35 percent of total urban use (California Department of Water Resources 2009).

Many factors contribute to the large amount of water used in residential landscapes, including population shifts to hotter interior regions, which often have larger residential landscapes (Hanak and Davis 2006); the prevalence of cool-season turf grasses and other high-water-use plants; irrigation systems that are inefficient and poorly maintained; and widespread overwatering of all plant types.

When comparing homeowners' actual landscape water use to a theoretical water requirement, one sees a mix of irrigation behaviors: homeowners who under-irrigate and those who over-irrigate (Irvine Ranch Water District 2011). It can be assumed that most of those who under-irrigate are nevertheless satisfied with the quality and appearance of their landscapes; otherwise, those homeowners would have increased their water use.

There are at least two possible explanations for this phenomenon: Either some landscapes require less water than previously thought, because actual plant water needs, soil conditions, and cultural factors contribute to a lower demand, or the standard used to estimate the theoretical water requirements needs to be reevaluated. It is apparent that many landscapes are successfully irrigated at rates below the current theoretical requirement.

Prior to 2010, landscapes that were installed in compliance with the Model Water Efficient Landscape Ordinance (MWELO) (California Code of Regulations Title 23, Division 2, Chapter 2.7, Section 490) were allowed a water budget that did not exceed an evapotranspiration adjustment factor (ETAF) of 0.8. (For more explanation on the ETAF, see the reference for California Department of Water Resources 2008, listed at the end of this chapter under the “References Cited” heading.) When the MWELO was updated in 2010, the water budgets for most landscapes were reduced so that they may not exceed an ETAF of 0.7. The Landscape Task Force recommended that the ETAF be reviewed every 10 years for possible further reduction (California Urban Water Conservation Council 2005b). After more research is completed in plant water needs, it may be appropriate to lower the ETAF used in the water budget calculation.

In light of these findings, water suppliers would benefit from targeting their most resource-intensive landscape conservation efforts to water users that are over-irrigating (Irvine Ranch Water District 2011). As a marketing tool, a cost-benefit analysis based on water rates and other factors can help determine which customers would be the best candidates for intervention, both in terms of maximizing water supplier resources and customer buy-in. Furthermore, because most residential users underestimate the quantity of water used in their landscape (California Urban Water Conservation Council 2007c), education components remain a vital tool in that they increase the water savings potential.

Several water use studies (Pacific Institute 2003; Irvine Ranch Water District 2001; Hanak and Davis 2006; Irvine Ranch Water District 2011) indicate that residential landscape water demand can potentially be reduced by at least 20 percent, with some researchers estimating savings potential of 45 percent or more (Pacific Institute 2003).

The statewide average baseline water use for residential landscape irrigation is estimated at 81 gpcd (from a total baseline water use of 198 gpcd). This is derived as follows: Baseline residential outdoor use is 3.0 maf (see Table 3-2), divided by a 2000 population of 33,780,000, and then converted to gpcd.

A conservative estimate of 20-percent reduction in residential landscape water use would represent a savings of 16.2 gpcd, equating to an annual statewide reduction of 0.79 maf by 2020.

Large Landscapes (Dedicated Meters)

Large landscapes are commercial, industrial, and institutional (CII) landscapes that are a category set apart by the presence of dedicated irrigation meters. Dedicated metering serves the purpose of accurately measuring the water use of a landscape and making it possible to assign and monitor water budgets and detect leaks. The CUWCC landscape BMP (formerly BMP 5) requires water use budgets to be assigned at 70 percent of local reference evapotranspiration (ETo).

Based on an eight-year average of DWR data (see Table 3-1 and Figure 3-3), large landscapes with dedicated meters accounted for 10 percent of urban water use or 0.8 maf. Water use through a dedicated landscape meter can be monitored by the irrigator and can provide immediate feedback on the amount of water moving through the meter. Programs such as the California Landscape Contractors Association (CLCA) Water Management Certification Program (WMCP) (California Landscape Contractors

Association 2012) enable irrigation managers to monitor and track water use and manage a landscape at 80 percent of ETo or less.

PLACEHOLDER Box 3-5 Dedicated Water Meters: California Water Code Section 535

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The numbers and total acreage of sites designated as large landscapes will increase over time as mixed-use meters at existing CII landscapes are retrofitted to dedicated meters. All new CII landscapes over 5,000 square feet require a dedicated irrigation meter and are more accurately known as “large landscapes.”

A CII landscape water use efficiency study (California Landscape Contractors Association 2003) collected data from 449 CII landscapes. The results indicate that approximately 50 percent of CII landscapes were irrigated in excess of 100 percent ETo. If those sites reduced water use to maintain a water budget of 100 percent ETo, the author estimates a 15-percent demand reduction could be achieved. Potential landscape efficiency gains could be much greater than 15 percent if conversions from cool-season turf to water efficient plants were included and if the water budget were reduced to seventy or eighty percent of ETo.

Recent WMCP information from the CLCA Water Forums indicates that many sites maintained and managed under the WMCP are performing at water budgets of 80 percent of ETo or less, with average irrigation rates of 64 percent of ETo for the 704 sites enrolled in the WMCP in 2012 (California Landscape Contractors Association 2012).

However, some water suppliers have found that after assigning water budgets and conducting outreach efforts, they are still not seeing the savings estimated in the 2003 CLCA CII landscape study, nor do they believe potential for further savings is as great (Brown pers. comm. Oct. 26, 2012). Other suppliers have seen a drop in landscape water use but attribute these savings not only to the training programs, but also to pricing, shortages, and other factors as well (Granger pers. comm. Oct. 19, 2012).

Newer study results will give a more current picture of CII landscape water use efficiency, but it is clear that sites that are actively managed by trained personnel are generally the most efficient and still retain potential for further savings.

Statewide average baseline water use for large landscapes is estimated at 21 gpcd. Using a conservative estimate of a 15-percent reduction (3 gpcd), annual demand reduction by the year 2020 would be approximately 0.15 maf.

Commercial, Industrial, and Institutional Landscapes (Mixed-Use Meters)

Opportunities for water savings in CII landscapes with mixed-use meters are probably as high as residential landscapes; however, significant data gaps exist due to inconsistencies in water use reporting. Suppliers voluntarily report their public water supply production and, depending on the agency, landscape water use may be included in CII, multi-family, or “other” categories. Because of these data gaps, potential water savings in CII landscapes with mixed-use meters cannot be separated from CII water use and are included as part of CII water savings, discussed later in this chapter.

Indoor Residential Water Use

Indoor residential water use (both single and multifamily housing) accounts for about 31 percent of total urban water use in California (See Figure 3-3 and Table 3-2). This equates to a statewide average baseline water use for indoor residential of 62 gpcd. This is derived by using 8.8 maf for the total annual urban water use (California Department of Water Resources 2009) and 33,780,000 for the 2000 population.

A comparison of California's baseline indoor residential water use, 62 gpcd, to a study of homes retrofitted with WaterSense and Energy Star fixtures and appliances (U.S. Environmental Protection Agency 2008), which had water use of 43 gpcd, shows that significant savings remain to be captured in this sector.

Residential indoor water is delivered through only a small number of fixtures — toilets, clothes washers, showers, faucets, and dishwashers. The percentage of water use by fixture is displayed in Figure 3-4. The following paragraphs address these fixtures, and potential savings, in more detail. Several regulations mandate high-efficiency fixtures. A discussion and comparison of these regulations is provided by the California Urban Water Conservation Council (2010).

PLACEHOLDER Figure 3-4 Estimated Indoor Residential Water Use in California (Year 2000)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Toilets

A study by American Water Works Association (AWWA) Research Foundation (1997) revealed that toilets were the biggest component of indoor water use at that time. Many older, inefficient toilets have been replaced with more efficient models since then, but, years later, it appears that toilets are still the largest user of indoor residential water use. More current studies (Pacific Institute 2003; Irvine Ranch Water District 2011) show that toilets account for 20 percent to 33 percent of indoor water use, which equates to an average of 13-19 gpcd.

Older toilets use 3.5 or 5 gallons per flush (gpf), but regulations have mandated increased efficiency. The 1992 California code required that new toilets sold in the marketplace have a flush volume of 1.6 gpf. These are called ultra low-flow toilets (ULFTs). In 2014 the code will require an even greater efficiency of 1.28 gpf. These toilets are known as high-efficiency toilets (HETs) and have been mandated in new construction since 2011.

Many existing toilets remain to be converted to efficient models. Estimates are that the saturation of ULFTs and HETs is 54 percent to 60 percent. (Irvine Ranch Water District 2011; 20x2020 Agency Team on Water Conservation 2010).

The 20x2020 Plan calculates that retrofitting residential toilets, so that 81 percent are ULFT or HET, could save roughly 5 gpcd.

Clothes Washers

Clothes washers account for 14 percent to 18 percent of indoor residential water use (Pacific Institute 2003; Irvine Ranch Water District 2011), which is about 9-10.5 gpcd. However, according to the

California Single Family Home Water Use Efficiency Study (Irvine Ranch Water District 2011), only about 20 percent of homes studied in 2007 were using efficient washers. This indicates that there is great potential for decreasing per-capita water use for clothes washing through appliance replacement.

The water efficiency of clothes washers is rated using the term “water factor.” The water factor is measured by the quantity of water (gallons) used to wash each cubic foot of laundry. The lower the water factor rating, the more water-efficient the clothes washer.

Standards for the water efficiency of residential clothes washers have been put in place by the U.S. Department of Energy. These water factor standards have been moving progressively lower over several years. The most current standard will culminate in 2018 with a maximum water factor of 6.0 for standard top-loading machines and a maximum water factor of 4.5 for standard front-loading machines. For comparison, conventional washers have a water factor of 12 to 13.

The 20x2020 Plan estimated that potential savings from efficiency codes, active rebate programs, and natural turnover of clothes washers would equal 4-6 gpcd.

Leaks

Studies from Pacific Institute (2003) and Irvine Ranch Water District (2011) reveal that the water lost to leakage in the residential sector averages from 7 to 10 gpcd. This number is relatively large; however, the majority of the water loss was concentrated in a small number of homes. The median loss was found to be small, between 1.4 and 3.9 gpcd. Yet, 14 percent of the homes lost more than 17 gpcd to leaks, and 7 percent of the homes were leaking more than 34 gpcd. This variability suggests that leak reduction programs that target the homes with the highest leakage rates would be the most cost-effective for a water supplier.

Water suppliers can employ several methods to detect homes with high rates of leakage, including:

- Developing water budgets. Homes with leaks will exceed their water budgets and pay excess use rates, thus encouraging repair.
- Installing advanced metering infrastructure (AMI). AMI monitors water usage in real time, sampling hourly to every 15 minutes. Because of the frequent monitoring and collection of water use data, a constant flow (leak) can be detected quickly and efficiently.
- Identifying excessive water users (by comparison of water bills with similar properties) and offering water audits to these customers.

PLACEHOLDER Box 3-6 Case Study: City of Sacramento Advanced Metering Infrastructure

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

If leaks were to be detected and repaired at homes with high leak rates, so that the average losses due to leaks were reduced to the median values (1.4-3.9 gpcd), the savings would be 6-7.5 gpcd (Pacific Institute 2003; Irvine Ranch Water District 2011).

Conservatively estimating that, on a statewide average, water agencies were able to work with their residential customers so that just less than half of this potential leakage could be detected and repaired, the savings would then be 3 gpcd.

Showers

Showers account for about 21 percent of indoor residential use, equivalent to about 11.8-13.5 gpcd.

A study by Irvine Ranch Water District (2011) found that nearly 80 percent of all homes had showerheads operating at 2.5 gallons per minute (gpm) or less (the federal standard, as specified by the Energy Policy Act of 1992). WaterSense-rated showerheads have a maximum flow rate of 2.0 gpm or less, producing even greater savings. Further savings in shower water use can be achieved by continued retrofitting of inefficient shower heads and public education campaigns that include messages to take shorter showers.

The 20x2020 Plan estimates that the potential water savings remaining to be captured in shower water use are roughly 1 gpcd.

Faucets

Faucets account for about 19 percent of indoor use, approximately 11-12 gpcd.

The maximum flow rate for new faucets, set by federal standards in 1994, is 2.5 gpm, though some faucets, especially bathroom faucets, can operate as low as 0.5 gpm. The 1997 AWWA Research Foundation study estimated a 50-percent penetration of 2.2 gpm faucet aerators.

Savings in faucet water use can be achieved by continued retrofitting with low-flow fixtures and aerators and public education campaigns that include messages to "turn off the tap" when water is simply going down the drain.

The *California Single Family Home Water Use Efficiency Study* (Irvine Ranch Water District 2011) assumes a reduction of 10 percent in faucet water use (11.5 gpcd X 10 percent = 1 gpcd). This equates to a savings of 1 gpcd.

PLACEHOLDER Box 3-7 Multi-Family Dwellings and Sub-Metering

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Total Projected Savings for Indoor Residential

Adding the savings from each of the fixtures and appliances above, total projected water savings for indoor residential use is 15 gpcd (Table 3-3).

PLACEHOLDER Table 3-3 Potential Savings for Indoor Residential Water Use

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Commercial, Industrial, and Institutional Sectors

The CII sectors cover a broad range of water uses, from schoolyard playgrounds and drinking faucets to bottling plants and restaurants. It is, therefore, a challenge to address these sectors, whether trying to make broad generalizations about CII water use as a whole or trying to drill down and find detailed data on any particular use. The State does not currently have the data necessary to establish the baseline of use in each CII subsector, and the information needed to estimate statewide savings must await the development of baselines and metrics.

The CII sectors (not including large landscapes) use about 20 percent of urban water, which equates to 1.7 maf per year, or approximately 48 gpcd (California Department of Water Resources 2009, 2012a; Pacific Institute 2003; 20x2020 Agency Team on Water Conservation 2010).

If water used for large landscapes is added to CII water use, the total CII water use would then be approximately 30 percent of urban water use. The 30-percent figure is often quoted for CII water use. However, water use for large landscapes will not be discussed in this section, as it has been addressed in the "Landscape Irrigation" section earlier in this chapter. The CII landscapes with mixed-use meters (indoor and outdoor use on one meter) are included in this section, because they are distinctly different from large landscapes, such as parks and golf courses.

Commercial, Industrial, and Institutional Water Uses

There are limited centralized data concerning how much water is used in the CII sectors. Data on the numerous end uses are even more scattered. However, water uses within the CII sectors can be grouped into the following common uses (Pacific Institute 2003; California Department of Water Resources 2012a): process, restrooms, cooling, landscaping, kitchen, and laundry. With the exception of process water use, these end uses are very similar among CII users.

- Process — Process water inefficiencies include poorly adjusted equipment; leaks; use of outdated technology or equipment that is not water-efficient, or both; and use of potable water where alternatives, such as recycled or reused water, or waterless processes may be appropriate.
- Restrooms — Restroom usage is one of the higher end uses in CII. Inefficiencies in this area are similar to those in the residential sector; these include older toilets with high-volume flush rates and high-volume faucets. Waterless and low-flow urinals are components unique to the CII sectors, and these have brought significant savings to CII customers.
- Cooling — Water is used for cooling heated equipment, cooling towers, and air conditioning. Inefficiencies include improper adjustments made by system operators; system leaks; and the use of older, inefficient equipment.
- Landscape — Inefficiencies in CII landscape, as with other landscapes, include poorly designed and maintained irrigation systems, excessive watering schedules, and landscape designs that rely on high-water-using plants, especially cool-season turf, where low-water-using plants could provide the same benefit.
- Kitchen — The majority of the water used in the kitchens is for pre-rinsing, washing dishes and pots, making ice, preparing food, and cleaning equipment. Pre-rinse spray-valve retrofit programs have been, and continue to be, effective water efficiency programs. Inefficiencies in kitchen water use include usage of old machines, high-volume spray valves, and cooking practices and techniques.
- Laundry — Water savings can be achieved through use of more efficient washers.

PLACEHOLDER Box 3-8 Process Water

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Water Recycling and Reuse in the Commercial, Industrial, and Institutional Sectors

The use of recycled water (treated municipal effluent) or the reuse of process water within an industrial facility can play an important part in reducing CII water demand. With appropriate management, many non-potable water uses can be supplied with these alternate sources, such as cooling, washing, irrigation, and toilet flushing.

Recycled water provides 209,500 af of fresh water a year to CII sectors, including power plants. Saline water use from coastal sources also provides additional water primarily to the mining and steam electric power plants, estimated at 14.5 maf per year (California Department of Water Resources 2012a).

Water reuse opportunities exist in almost all industrial plants and are a growing focus of industry. Water reuse can range from reusing relatively clean rinse water for initial washing processes to the capture of rainwater or air conditioning condensate for use in irrigation or a cooling tower.

Water Agency Actions

Each water agency will face a unique blend of CII customers and will need to tailor the implementation of their CII water conservation program to fit local needs and opportunities. However, certain actions will assist water agencies in increasing CII water use efficiency to meet 2020 targets. These include identifying the highest users of CII water within the agency and offering or otherwise supporting water use surveys for these customers, continued and more aggressive conversions of mixed-use meters to dedicated landscape meters, and continued retrofitting of older toilets to ULFT and HET.

Commercial, Industrial, and Institutional Task Force

In response to the complexity of the CII sectors and the lack of data available on CII water use, the SB X7-7 legislation called for a Commercial, Industrial, and Institutional Task Force (CII Task Force) to address CII water use efficiency, including development of alternative BMPs and metrics for water use in CII sectors, as well as identifying barriers to the use of recycled water. The CII Task Force wrote a report of its findings and recommendations to the Legislature (California Department of Water Resources 2012a).

Assessment for Appropriateness of Best Management Practices

The CII Task Force identified a wide range of BMPs for use in the CII sectors. All of these BMPs are technically feasible and cost-effective in certain situations; however, the appropriateness of using any single BMP must be assessed for each site by the site operator or owner. The CII water user would need to conduct an audit of the site to determine which BMPs would be technically feasible and conduct a cost/benefit analysis to determine whether it is cost-effective to implement the BMPs. Organizations representing business and industry, water suppliers, the CUWCC, and DWR should educate CII businesses on the BMPs and approaches to doing audits and a cost-effectiveness analysis.

Commercial, Industrial, and Institutional Task Force Recommendations

The CII Task Force draft report (California Department of Water Resources 2012a) includes the following recommendations:

- **CII Best Management Practices**
  - Although many CII water users have implemented water efficiency measures, much more remains to be done in these sectors. CII customers should be encouraged to implement the BMPs identified in the CII Task Force report, such as:
    - Adjusting equipment and fixing leaks.
    - Modifying equipment, installing water-saving devices, and improving operational efficiencies.

        - Using automated systems.
        - Replacing older, inefficient equipment with new, water-saving equipment.
        - Reusing water on site or using recycled municipal wastewater.
    - CII customers should perform audits to identify opportunities for BMP implementation and implement all cost-effective BMPs.
- **Efficiency Standards and Metrics**
    - The appropriate entities should set efficiency standards for certain water-using devices and equipment, similar to existing device standards for commercial pre-rinse spray valves and clothes washers. Codes and standards could be updated to reflect the most current efficiency standards.
    - Develop appropriate metrics for tracking CII water use efficiency improvements.
- **Recycled and Alternative Water Use**
    - Improve statutory and regulatory requirements to overcome barriers to the use of recycled water in a manner that is protective of public health and the environment.
    - Stakeholders and DWR should encourage financial and technical assistance to increase recycled and alternative water use.
- **Ongoing Support**
    - DWR and the CUWCC should identify and develop a mechanism to ensure that critical issues in CII water conservation are addressed.
    - Improve statewide collection of water use data to better characterize and track water use in the CII sectors.

PLACEHOLDER Box 3-9 California Prisons Reduced Annual Water Use by 21 Percent

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Projected Commercial, Industrial, and Institutional Savings

Because of the lack of sufficient water use data for the CII sectors, and the fact that water conservation potential varies greatly among technologies, industries, and regions, determining a value for projected savings is challenging.

However, the SB X7-7 legislation and the CUWCC MOU both point to a target savings in the CII sectors of 10 percent from the baseline. In order to maintain consistency with the legislation and the MOU, DWR will also use the value of 10 percent to project CII water savings.

These potential CII water savings exclude savings from large landscapes, which are included in the “Large Landscapes (Dedicated Meters)” portion of this chapter.

The volume of potential savings in the CII sectors (af) is derived by multiplying CII baseline water use (1.76 maf) by the assumed 10-percent reduction (1.76 maf X 10%). The resulting savings are 176,000 af, which equates to 4.8 gpcd.

Water Loss Control in Distribution Systems

This section addresses water loss due to leaks in the distribution system of a water supplier. Leaks in the residential and CII sectors are addressed in their respective sections of this chapter.

Water loss control consists of the auditing of water supplies and implementation of controls to keep system losses to a minimum. A report by Southern California Edison (2009) estimated that 10 percent of the total volume of water supplied statewide is lost to leaks, which equals 0.88 maf. Addressing this loss is a major challenge to water suppliers, many of whom have aging water distribution systems in need of repair yet lack adequate funding for extensive water main replacement.

Audits

Water auditing is crucial to identifying the economically viable options that can be implemented for water loss control. Water utilities that do not perform water audits are most likely to be unaware of the level of real losses in their systems, making it unlikely for them to implement BMPs to curb these loss volumes.

A new standard method for conducting water audits was co-developed by the American Water Works Association (AWWA) and the International Water Association (IWA). The AWWA/IWA water audit method is effective because it features sound, consistent definitions for the major forms of water consumption and water loss encountered in drinking water utilities. It also features a set of rational performance indicators that evaluate utilities on system-specific attributes, such as the average pressure in the distribution system and the total length of water mains.

The AWWA/IWA water audit method is detailed in the AWWA's manual *Water Audits and Loss Control Programs* (2009). The AWWA also offers free software for this auditing method that assists in tracking water consumption and losses and calculates the costs of losses, giving agencies important information for assessing the cost-effectiveness of leak reduction measures.

This new standard water audit is now a requirement for implementation of BMP 1.2 (see Table 3-1 for a list of all BMPs). All water agencies that are members of the CUWCC, as well as any agencies that seek funding from the State of California, are obligated to complete the standard water audit annually, to improve the quality of data collected on water loss, and to reduce water losses to the extent that is cost-effective.

Trenchless Pipe Repairs

Repairing leaky pipes can be an expensive and difficult proposition for agencies. Trenchless pipe repair is an emerging, cost-effective technology that offers an efficient alternative in pipe repair. Using this new technology, the damaged pipe is lined with a new cured-in-place pipe that seals all cracks, splits, and faulty joints. This trenchless technology requires no trenching or digging and can be done in much less time without large excavations, saving money, time, and labor and making repairs and maintenance more cost-effective.

Meters

Measurements of water use are a necessary component in developing water budgets and detecting leaks. Consumers and water agencies are aware of water use when it is being metered and monitored. The water use data can be mapped for trends to detect water loss. Consumer awareness leads to higher implementation of BMPs to conserve water. The 2010 DWR Public Water Systems Statistics estimates that 6 percent to 7 percent of connections in California are still unmetered. There are huge potential savings by metering water use. The CUWCC, in its memorandum of understanding (MOU), BMP 1.3, estimates a 20-percent savings when water meters are installed (California Urban Water Conservation Council 2009).

As of 2012, the California Water Code required full metering for customers of all urban water suppliers served by the federal Central Valley Project (CVP) by 2013. Full metering is required by 2025 for customers of all other urban water suppliers with unmetered service connections.

Although water meters aid in preventing water loss, a recent study by the U.S. Environmental Protection Agency (EPA) and the Water Research Foundation (2011) shows that water meters in service lose their accuracy through use. Low flows of 1/8 gpm may go unrecorded by meters that are set to run at 1/4 gpm. Water meters often need to be recalibrated and checked. Higher accuracy standards should also be considered to capture a greater share of low flows that are indicative of leaks.

Projected Savings

A report by Southern California Edison (2009) concluded that 40 percent of water loss is economically recoverable. Given that the estimated water loss in California is 0.88 maf, and that 40 percent of that is estimated to be economically recoverable, the calculated water savings from cost-effective water loss control is 0.35 maf, or 7 gpcd.

Combined Demand Reductions

Combining the estimated demand reductions from each sector, as detailed in the preceding paragraphs, the State of California could theoretically reduce demand for potable water in the year 2020 by more than 2 million af (Table 3-4).

PLACEHOLDER Table 3-4 Projected Savings by Sector

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Alternative Water Sources — Recycled Water, Desalinated Water, Gray Water, and Rainwater

Alternative water supplies are expected to further reduce statewide demand of potable water by the year 2020.

Alternative water sources vary in water quality, level of treatment, local availability, and suitability for intended uses. Recycled water and desalinated water undergo the highest level of treatment prior to use and are discussed in detail in Chapters 12 and 10 of Volume 3.

Residential rainwater capture and gray water reuse are sources of water that can be used without the high investment in infrastructure that recycled water or desalinated water require.

Rainwater capture is discussed at length in Chapter 20, “Urban Stormwater Runoff Management,” but it should be mentioned here that on-site rainwater capture, in the form of rain gardens, bioswales, pervious surfaces, and other landscape features, can reduce the amount of potable water needed for irrigation by replenishing soil moisture levels and shortening the irrigation season. A small to moderate-sized rain garden can collect thousands of gallons of water. For example, a demonstration rain garden at the Richardson Bay Audubon Center & Sanctuary in Marin County (Salmon Protection and Watershed Network 2010) can collect nearly 3,900 gallons of water in a 315-square-foot rain garden with approximately 22 inches of annual rainfall.

Although there is tremendous interest in rainwater capture with rain barrels and cisterns, California's dry summer climate brings into question the cost-effectiveness of small rain capture devices in many regions of the state. However, cisterns and other large-volume storage devices begin to become cost-effective in areas where the rainy season extends into the irrigation season or where supplied water is very expensive, unreliable, or difficult to convey. Unlike rainwater capture for irrigation, in which supply availability and demand are out of sync, rainwater capture for year-round indoor non-potable uses, such as toilet flushing, may be the most practical application. Rainwater standards are printed in the 2013 California Plumbing Code.

During the 2013 triennial code cycle, gray water standards were revised by the California Building Standards Commission (CBSC) and the Department of Housing and Community Development (HCD) and were organized in Chapter 16 of the California Plumbing Code. Gray water use will increase over time, partly due to changes in the gray water standards. The revised standards make it easier for a water user to install a gray water system; simple systems supplied by clothes washers or single fixtures do not require a building permit if certain conditions are met.

In its 2010 UWMP, the Los Angeles Department of Water and Power features a case study of alternative water use by one of its residential customers. In addition to collecting rainwater in 18 rain barrels, the customer installed a gray water system using the waste water from her clothes washer. The clothes-washer-supplied gray water system generates approximately 7,000 gallons of water per year by the family of three. By adding the shower and bathroom sink to the gray water system, the water generated for landscape irrigation could exceed 53,000 gallons of gray water per year.

The *California Single Family Home Water Use Efficiency Study* (Irvine Ranch Water District 2011) found that the annual estimated irrigation demand averages about 90,000 gallons per year at the homes studied. Based on this assumption, this family could offset nearly 60 percent of its irrigation demand by the expanded gray water system. Under the new gray water standards, a plumbing permit is not required if the plumbing is not altered and if health and safety conditions are met.

The Importance of Conservation Rate Structures

Conservation rate structures are rates set by water agencies to provide price signals to consumers and encourage water conservation. Conservation rates are also known as volumetric rates, because the customer bill reflects the volume of water used. These structures can be applied to water supply as well as wastewater (sewer) services.

Properly constructed rates can be significant in motivating customers to save water. When determining conservation rate structures, water suppliers must also ensure revenue stability. This is done through a combination of variable and fixed revenues, which ensure that adequate funds are provided to operate and maintain the system even when water use is declining.

PLACEHOLDER Box 3-10 Consumption-Based Fixed Rates, City of Davis

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Some examples of conservation rate structures are listed below.

- Increasing block tier structures: The cost per unit of water increases as the consumer uses more water.
- Seasonal rates: Water rates are set higher during the summer months, when peak usage occurs.
- Water budget structures: Each residence has an inclining block rate structure designed according to the number of occupants, landscape area, local climate, and possibly other factors. The prices of the tiers increase significantly after the base usage tier has been reached.
- Water budgets with punitive tiers when budgets are exceeded: Often the revenue generated from punitive tiers is used to fund the conservation programs.

Flat rates, where customers' bills do not reflect the volume of water used, are not considered conservation rates because they do not send a price signal to the consumer and do not encourage conservation.

PLACEHOLDER Box 3-11 Successful Conservation Rate Structure: Irvine Ranch Water District

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Conservation Rate Structures for Wastewater Services

Although roughly 90 percent of California households served by a public water supplier pay for drinking water through a volumetric rate, about 70 percent of such California households pay for sewer service through a flat, non-volumetric charge. And sewer charges can be significant: In some jurisdictions sewer charges can be equal to, or greater than, water charges. By billing sewer service at a flat rate, the price signal rewarding water efficiency is being cut in half for a majority of California households.

Water efficiency can reduce future infrastructure requirements for sewer service, and volumetric pricing for sewer service is encouraged by the EPA, the Water Environment Federation, and the CUWCC.

Installation of new hardware is generally not required in order to begin volumetric billing for wastewater, but where water and sewer are provided by different agencies, interagency cooperation is needed, and billing software modifications are likely (Chesnutt et al. 1994). Volumetric wastewater pricing requires access to metered water consumption records and the ability to generate a customer bill. Sewer agencies currently billing fixed charges on a combined water-wastewater bill would have the fewest implementation constraints. A sewer agency whose service area cuts across multiple water agency service area boundaries would face more implementation challenges.

A 2011 report (A&N Services Inc. 2011) presented a roughly 4-percent reduction in residential water use, with a 10-percent sewer service rate increase.

Potential Benefits

Urban Water Use Efficiency

Using water efficiently yields multiple benefits, including:

- Increased reliability of water supplies.
- Increased capacity to meet the growing water demand of California's increasing population.
- Delayed capital costs for new infrastructure to treat and deliver water.

- Reduced contaminated irrigation runoff to surface waters.
- Reduced volume of wastewater, thus reducing capital costs and ongoing treatment costs.
- Increased availability of water for surface or groundwater storage.
- Reduced water-related energy demands and associated greenhouse gas (GHG) emissions.

PLACEHOLDER Box 3-12 Reducing Irrigation Runoff Helps Local Waterways

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 3-13 Climate Change and Water Use Efficiency: the Energy-Water Nexus

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Climate Change

Urban water suppliers and water users may be particularly vulnerable to changes in climate because they require highly reliable water supplies and because demands for water tend to grow over time with population. While some agricultural water users may be able to temporarily reduce water use by fallowing land or changing cropping patterns, urban water uses tend to have much less flexibility. Urban water use efficiency provides a key strategy for addressing these vulnerabilities.

Key impacts of climate change that relate to urban water supplies include:

- Warming temperatures, increasing water usage, particularly for outdoor irrigation.
- Decreasing snowfall, reducing the natural water storage found in the Sierra Nevada snowpack.
- Precipitation shifting from snow to rain, requiring a change in water supply management.
- Rising sea levels:
  - Threatening water supply infrastructure in coastal communities.
  - Increasing seawater intrusion into coastal freshwater aquifers.
  - Reducing water exports from the Delta.
- Increasing frequency of floods, droughts, and wildfires damaging watersheds that provide water to urban communities.

To help address these climate-related challenges, State and federal agencies have developed several programs that provide guidance and information to urban water suppliers. In 2011, the DWR, the EPA, the U.S. Army Corps of Engineers, and the Resources Legacy Fund cooperatively developed *Climate Change Handbook for Regional Water Planning* (online at http://www.water.ca.gov/climatechange/CCHandbook.cfm), which provides a comprehensive resource for regional water managers but includes information that will be useful to urban water managers as well. Even more focused on urban water providers is the U.S. EPA's Climate Ready Water Utilities program (online at http://www.epa.gov/infrastructure/watersecurity/climate), which provides guidance and tools specifically for water utilities to incorporate climate change into their planning and operations.

Adaptation

Water conservation and water use efficiency are considered primary climate change adaptation strategies — those that should be undertaken first because they are generally lower-cost and provide multiple benefits. By implementing practices that make the most of available water supplies, practices that reduce waste and increase efficiency, the urban water use sector will be better equipped to adapt to potential reductions in water supply.

Mitigation

Supplying and treating water for urban use requires a high amount of energy, which in turn contributes to greenhouse gas emissions and climate change. Reducing the amount of water used in the urban setting reduces the energy used, thus mitigating impacts to climate change. Urban water use efficiency is both a mitigation measure and an adaptation measure for climate change. Box 3-13 highlights the connection between urban water use, energy, and greenhouse gases.

Potential Costs

Increasing the supply of water has the same effect on water availability as decreasing the demand for water (through increased efficiency). However, historically reliable methods for increasing supply, such as building new dams for surface storage, or increasing water exports from the Delta, are less certain as California moves into the future. Many water suppliers are turning to other strategies, such as improving efficiency, to meet increasing demand. And as the costs for increasing water supply go up, even the more expensive conservation strategies may become economically viable in the future.

Table 3-5 shows some examples of costs for water use efficiency practices. These costs will vary from supplier to supplier, but they are provided here as an illustration of what can be reasonably expected.

PLACEHOLDER Table 3-5 Sample Costs of Water Use Efficiency to Water Suppliers per Acre-Foot of Water Saved

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

It is conservatively estimated that a well-implemented set of water conservation programs would cost a water supplier an average of $333-$500 per af (Alliance for Water Efficiency 2008).

PLACEHOLDER Box 3-14 San Diego: Comparing Water Source Options

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

There are other important water conservation programs that cannot be quantified in terms of cost per af of water saved. These include designating and supporting a water conservation coordinator, implementing education and outreach programs, using water conservation rate structures, and developing and implementing a water waste prohibition ordinance.

Major Implementation Issues

Reduced Water Agency Revenue for Water Conservation

Because of the economic downturn, many water agencies have reduced their staff and other expenditures for water conservation. This reduction comes at a difficult time, when water agencies will need to increase, or at least maintain, the level of conservation in their districts in order to meet the 20-percent reduction by 2020.

Rate Structures and Water Agency Revenue

Providing customers with correct price signals to use water efficiently is not a simple task. The appropriate signals may vary from agency to agency and from community to community. And if the price structure is not set up correctly, the resulting water conservation can negatively affect the amount of revenue collected by a water supplier. The less water customers use, the less revenue the water supplier receives, which creates a disincentive for the water agency to encourage conservation. Also, because of seasonal variation in water use, some price structures may increase variability and fluctuation of water utility revenues.

This problem poses a hardship on the utility's ability to meet its revenue requirements and can undermine the financial viability of their systems and the ability to meet service needs and infrastructure maintenance.

The process for changing rate structures can also be challenging in and of itself. Regulations impose certain limitations, public support can be difficult to gain, and water board elections may influence the willingness of board members to agree to rate changes.

Lack of Public Awareness Regarding Landscape Water Use

Most homeowners are not aware that the majority of their water use takes place in the landscape, nor are they aware that much of that irrigation water is used inefficiently. In the 2007 *Statewide Market Survey: Landscape Water Use Efficiency* (California Urban Water Conservation Council 2007c), the researchers found that most respondents either had no idea how much water they used in their landscapes, or they believed their water use was below the statewide average. Coupled with the tendency to leave irrigation controllers on the default setting year round and a lack of irrigation system maintenance, a statewide education campaign is needed to educate water users and increase awareness of meaningful actions that will save water in landscapes.

Landscape Area Measurement for Water Budgets

Knowing the area of a landscape is critical to developing a water budget for the site. A water budget, in turn, will assist in determining whether the landscape is being watered efficiently.

Many water suppliers have not determined the extent of landscape area in their service area. Impediments to measuring or estimating landscape area include the high cost of physically measuring the site or purchasing satellite imagery, a lack of expertise in utilizing available satellite data, linking the parcels with customer data, segregating areas served by multiple meters, and assessing the density of vegetated canopies.

Inconsistent Implementation of the Model Water Efficient Landscape Ordinance

By the end of 2010, 333 local land use agencies had reported on the status of adoption of water efficient landscape ordinances. However, it is not known how consistently local agencies enforce water efficient landscape ordinances. Local agencies are challenged by the complexity of landscape and irrigation design requirements and a lack of staff to review and inspect landscape. The common disconnect between water suppliers and land use authorities further complicates the issue.

Data on Industrial Water Use Are Limited

The last survey published by DWR to obtain valid information on industrial water use (Bulletin 124-3) was conducted in 1979. This information is out of date, but no current data exist. The survey determined rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.

Water Loss

The amount of water lost due to leakage in the distribution system of the State's water suppliers is not well known. This is largely due to the fact that not all water suppliers perform regular water loss audits. If water audits are not conducted, it is difficult for a water agency to know the extent of its losses and unlikely that the agency will implement BMPs to reduce these losses.

Lack of a Standardized Efficiency Measure for California Urban Water Suppliers

One of the limitations to the development of the 20x2020 Plan goal was the lack of an effective measure of the level of water use efficiency in a supplier's service area. The gpcd is useful to track changes in water use in individual water agencies over time, but due to differences in landscape area, climate, and CII water use it is not useful as measure of efficiency. The lack of a standard measure of supplier efficiency is one reason that four different methods for setting a 2020 water use target were provided in the SB X7-7 legislation.

Recommendations

1. **Assist Utilities in Developing Sustainable Conservation Rate Structures —** DWR, in partnership with the CUWCC, the U.S. Bureau of Reclamation, the California Public Utilities Commission, the Association of California Water Agencies (ACWA), the California Water Association, and water agencies should lead an investigation to analyze and evaluate the effectiveness of rate structures in conserving water and meeting water agency revenue requirements. DWR should disseminate the findings and recommendations from the study, as well as guidance to water agencies, throughout the state by way of regional workshops and a detailed page on the DWR Web site.
2. **Expand the Save Our Water Campaign —** DWR, in coordination with ACWA, the CUWCC, water suppliers, local stakeholders, and irrigation manufacturers, should expand the statewide Save Our Water campaign. Initially, the landscape portion of the campaign should focus on cost-effective ways to improve irrigation system function and irrigation controller programming.
3. **Assist Water Agencies in Landscape Area Measurement and Water Budgets —** DWR, in coordination with the CUWCC, should assist water suppliers in finding easy and inexpensive ways to obtain landscape area data for parcels in their service areas and offer workshops that highlight successful programs. As a priority, water agencies should measure the landscape area for sites with dedicated meters first, because their landscape water use is known. A comparison

of water use and water budget will immediately determine if the landscape is being watered efficiently. Water agencies can then target the sites that are over-irrigating, a cost-effective method for reducing landscape irrigation demand.

4. **Increase Landscape Water Management Skills —** Water use efficiency is most easily achieved on landscapes with properly designed and installed irrigation systems and managed with water budgets. To make this possible, the Contractors State License Board should increase the emphasis and testing requirements in the C-27 Landscape Contractor's exam in the subject areas of irrigation design and installation and water budgeting to ensure landscape professionals have the needed skills. DWR, water suppliers, and the landscape industry should increase opportunities to improve water management skills of non-English-speaking workers and workers that do not hold a contractor's license.
5. **Update the Model Water Efficient Landscape Ordinance —** DWR should work with local agencies, local water suppliers, and the landscape industry to identify and remove barriers to implementation of the MWELO. The MWELO should be updated periodically based on new findings, innovation, and technological improvements.
6. **Encourage Innovation in Irrigation Equipment Design That Increases Durability, Reliability, and Ease of Use —** The irrigation manufacturing industry should work with the landscape industry, universities, and other industries to develop irrigation equipment, sensors, and controllers that are more durable and easier to install, maintain, and program.
7. **Update the Survey of Industrial Water Use —** Because the last published survey on industrial water use in California was conducted in 1979, and updated data are needed by local agencies and the State in order to better manage industrial water use, DWR should update the survey of industrial water use, Bulletin 124-3. The survey should provide information on the rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.
8. **Require Water Audits in 2015 Urban Water Management Plans —** In order to reduce water loss in water distribution systems, the Legislature should revise the Urban Water Management Planning Act to require water suppliers to complete the AWWA auditing program and report their water audit, water balance, and performance indicator in their 2015 UWMPs. Signatories to the CUWCC MOU are already required to perform this audit annually. Water audit data reported to the CUWCC provided valuable information on the extent of water losses that can be economically recovered by the water agencies. More on the AWWA auditing program can be found at http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx.
9. **Develop a Standardized Efficiency Measure for California Urban Water Suppliers —** Through a public process, DWR should develop a standardized water use efficiency measure for California urban water suppliers. The measure would be used to determine efficient water use for urban water suppliers and would account for differences in irrigated landscape area, climate, population, and CII water use. The single standardized measure for supplier water use efficiency would better permit customers, utilities, and State officials to evaluate the efficiencies of California urban water suppliers across the state.
10. **Investigate Gray Water Use in New Residential Applications —** In cooperation with water suppliers and developers, DWR should conduct a pilot study of gray water installation in new homes. The study should evaluate gray water use in landscapes and the feasibility of installing gray water systems in new homes.

Other Related Resource Management Strategies

Chapters within this volume that relate to urban water use efficiency are listed below.

- Chapter 9, “Conjunctive Management and Groundwater.”
- Chapter 10, “Desalination — Brackish Water and Seawater.”
- Chapter 12, “Municipal Recycled Water.”
- Chapter 8, “Water Transfers.”
- Chapter 15, “Drinking Water Treatment and Distribution.”
- Chapter 17, “Matching Water Quality to Use.”
- Chapter 20, “Urban Stormwater Runoff Management.”
- Chapter 24, “Land Use Planning and Management.”
- Chapter 25, “Recharge Area Protection.”
- Chapter 28, “Economic Incentives — Loans, Grants, and Water Pricing.”
- Chapter 29, “Outreach and Engagement.”

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Table 3-1 Best Management Practices

Foundational BMPs (ongoing practices implemented by all signatories to the MOU) [a]		Programmatic BMPs (practices with alternatives for implementation)	
BMP No.	**Description**	**BMP No.**	**Description**
BMP 1.1. Utility Operations Programs — Operations Practices	Designate a water conservation coordinator for the agency. Implement and maintain a water waste prohibition ordinance or regulation. Implement prohibitions on gutter flooding, single-pass cooling systems, and non-recirculating water. Monitor water softener efficiency and usage. *Old BMP numbers: 10, 12, and 13.*	BMP 3. Residential	Conduct indoor and outdoor residential water use surveys. Implement an enforceable ordinance or provide incentives to replace high-flow water use fixtures with low-flow counterparts. Offer rebates for high-efficiency washers. Offer rebates for high-efficiency, low-flow toilets. *Old BMP numbers: 1, 2, 6 and 14.*
BMP 1.2. Utility Operations Programs — Water Loss Control	Implement a full-scale system water audit, maintain in-house records of audit results and completed American Water Works Association audit worksheets. *Old BMP number: 3.*	BMP 4. Commercial, Industrial, and Institutional	Rank commercial, industrial, and institutional customers according to use. Implement either a CII [b] water use survey and customer incentives program or CII conservation program targets. *Old BMP number: 9.*
BMP 1.3. Utility Operations Programs — Metering	Install water meters for all new connections and bill by volume of use. Implement a program for retrofitting existing unmetered connections and bill by volume of use. *Old BMP number: 4.*	BMP 5. Landscape	Develop marketing and targeting strategies for landscape surveys. Implement water use budgets for large landscapes. *Old BMP number: 5.*
BMP 1.4. Utility Operations Programs — Pricing	Implement rate structures and volumetric rates for water service by customer class. *Old BMP number: 11.*		
BMP 2. Education Programs — Public Information Programs	Maintain an active public information program about water conservation. Implement a school education program to promote water conservation. *Old BMP numbers: 7 and 8.*		

Source: California Urban Water Conservation Council 2009.

Notes:

[a] BMP = best management practices. MOU = memorandum of understanding.

[b] CII = commercial, industrial, and institutional.

Table 3-2 Statewide Urban Water Uses

Sector	Percentage	Volume [a]
Residential landscape	35%	3.0 maf
Large landscape	10%	0.9 maf
Indoor residential	31%	2.7 maf
Commercial, institutional, and industrial	20%	1.7 maf
Other	5%	0.5 maf
Total	100%	8.8 maf

Source: California Department of Water Resources 2009.

Note:

[a] maf = million acre-feet.

Table 3-3 Potential Savings for Indoor Residential Water Use

Use	Savings [a]
Toilets	5 gpcd [b]
Showers	1 gpcd [b]
Leaks	3 gpcd [d]
Faucets	1 gpcd [c]
Clothes washers	4-6 gpcd [b]
Total	15 gpcd

Notes:

[a] gpcd = gallons per capita per day.

[b] Source: 20x 2020 Agency Team on Water Conservation 2010.

[c] Source: Irvine Ranch Water District 2011.

[d] Sources: Derived from Irvine Ranch 2011 and Pacific Institute 2003.

Table 3-4 Projected Savings by Sector [a]

Demand reduction sectors	Reduction [b]	Projected savings in 2020 [c]
Large landscape	3 gpcd	148,000 af
Commercial, industrial, and institutional	4 gpcd	197,000 af
Residential interior	15 gpcd	739,000 af
Residential exterior	16 gpcd	789,000 af
Water loss control	7 gpcd	345,000 af
Total	45 gpcd	2,218,000 af

Notes:

[a] The figures in this table are a summary of projected savings that are detailed in preceding pages.

[b] gpcd = gallons per capita per day.

[c] af = acre-feet.

Table 3-5 Sample Costs of Water Use Efficiency to Water Suppliers per Acre-Foot of Water Saved

Program types	Sample costs per acre-foot
Residential programs [a, b, c, d, e]	Toilet rebates: $158-$475/af
	Residential audits: $236-$1,474/af
	Clothes washer rebates: $154-$480/af
Landscape programs [a, b, d, e]	Landscape audits: $58-$896/af
	Equipment rebates: $15-$181/af
	Turf removal: $274-$717/af
	Water budgets: $10-$59/af
Commercial, industrial, and institutional (CII) programs [b, c, f, g]	Toilet rebates: $242-$1,018/af
	Urinal replacement: $320-$583/af
	Pre-rinse spray valves: $78/af
Utility operations programs [d, h]	System audits/leak detection: $203-$658/af

Notes:

[a] Source: City of Paso Robles 2010.

[b] Source: Los Angeles Department of Water and Power 2010.

[c] Source: California Urban Water Conservation Council 2004, 2005a, 2006, 2007a.

[d] Source: Marin Municipal Water District 2010.

[e] Source: City of Sacramento 2010.

[f] Source: East Bay Municipal Utilities District [date unknown].

[g] Source: Alliance for Water Efficiency 2012.

[h] Source: California Urban Water Conservation Council 2007b.

Figure 3-1 Average Baseline Water Use by Hydrologic Region

The map below displays the average water use, by hydrologic region, during the baseline period, roughly 1996 through 2005. The numbers displayed are in gallons per capita per day (GPCD) (California Department of Water Resources 2012b). The hydrologic regions near the coast generally have smaller landscapes and cooler climates compared with inland regions, which have larger irrigated landscapes and warmer climates.

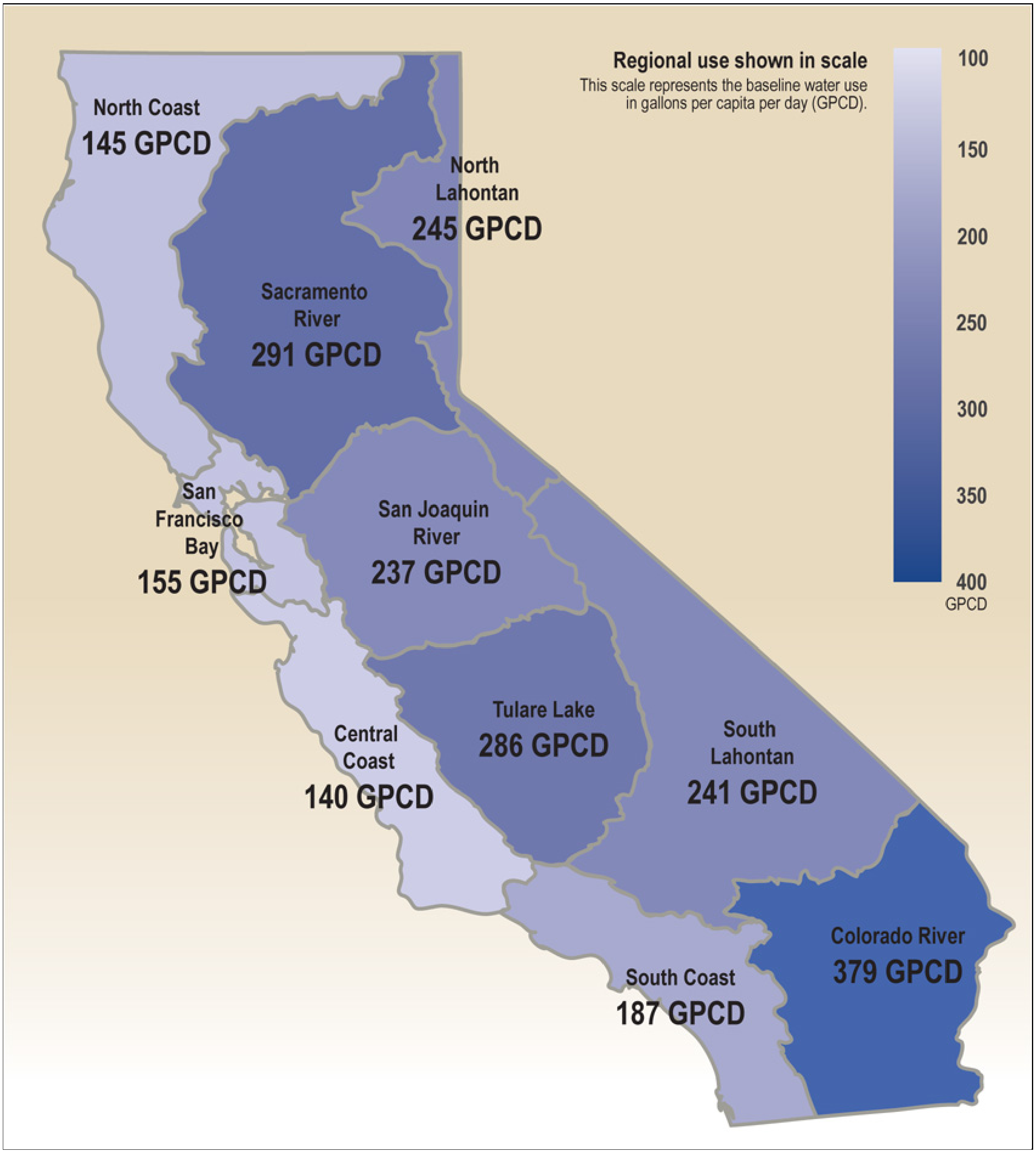


Figure 3-2 Baseline Water Use

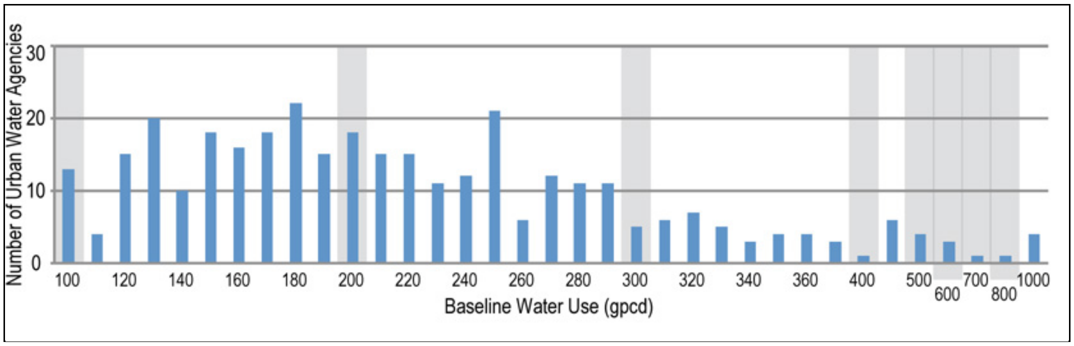
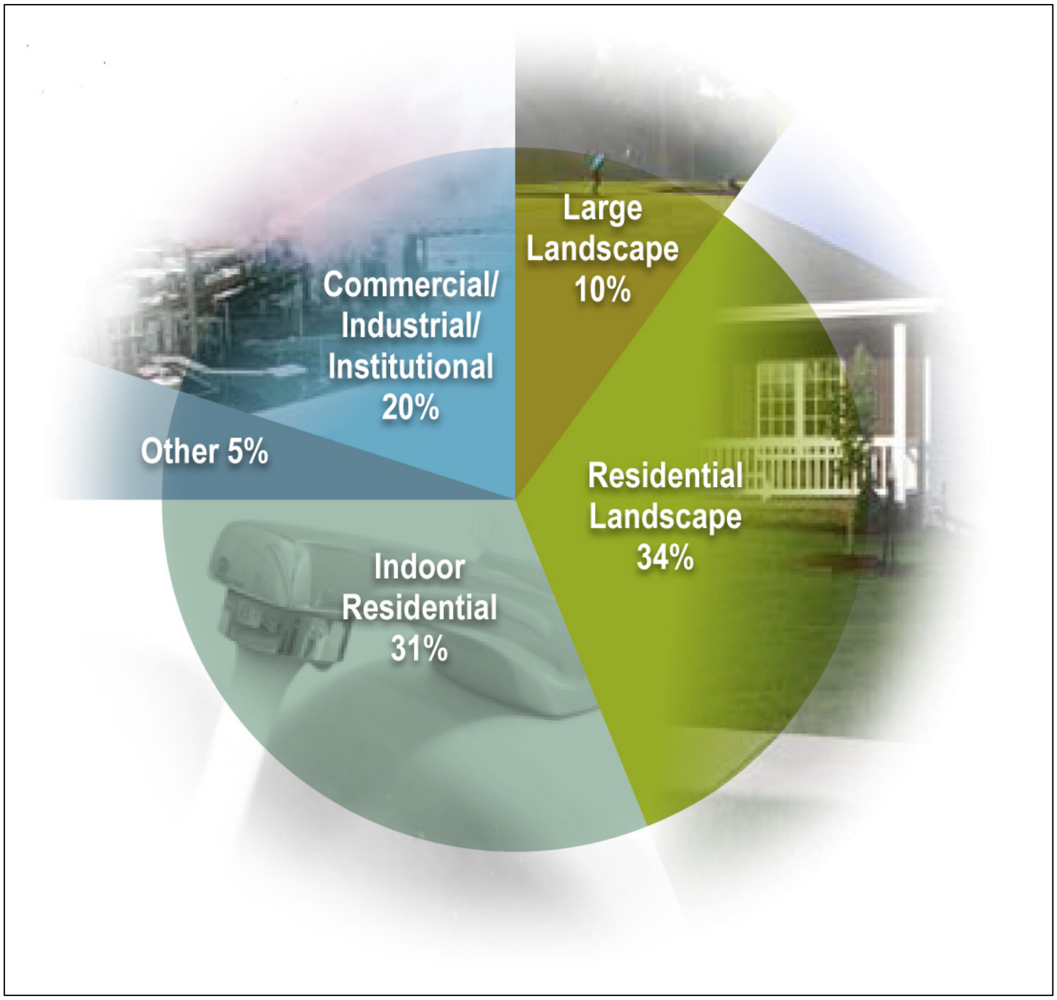


Figure 3-3 Statewide Urban Water Use: Eight-Year Average, 1998-2005

This pie chart illustrates the relative water use of different sectors as a statewide average. The water use by sector will vary for each individual water agency.



Source: California Department of Water Resources 2009

Figure 3-4 Estimated Indoor Residential Water Use in California (Year 2000)

Source: Pacific Institute 2003

Box 3-1 20x2020 Plan: History, Process, and Impact

History

In 2008, the Delta Vision Blue Ribbon Task Force called for improved water use efficiency and conservation in order to reduce exports from the Sacramento-San Joaquin River Delta (Delta). The task force specifically recommended a statewide 20-percent per-capita reduction in water use by the year 2020. In response to this recommendation, the 20x2020 Agency Team on Water Conservation was formed. The agency team subsequently wrote the *20x2020 Water Conservation Plan* (20x2020 State Agency Team on Water Conservation 2010) outlining recommendations on how statewide per-capita water use reductions could be successfully implemented to meet the goal of 20-percent reduction by 2020.

In November 2009, the Water Conservation Act of 2009, Senate Bill No. 7 of the 7th Extraordinary Session (SB X7-7), was enacted by the California Legislature (California Water Code Section 10608). The urban water conservation provisions of SB X7-7 reflect the approach taken in the *20x2020 Water Conservation Plan* and set an overall goal of reducing per-capita urban water use statewide by 20 percent by 2020.

The SB X7-7 legislation also directed the California Department of Water Resources (DWR) to address the following urban water use efficiency issues:

- Convene a task force to investigate alternative best management practices for the commercial, industrial, and institutional sectors (the Commercial, Industrial, and Institutional Task Force).
- Establish a standardized water use reporting form.
- Promote regional water resource management through increased incentives and decreased barriers.
- Develop statewide targets for regional water management practices such as using recycled water, using brackish groundwater, desalination, and urban stormwater infiltration and direct use.

The 20x2020 Plan Process

Water suppliers play a fundamental role in carrying out the statewide water reduction goal of 20 percent by 2020. Each urban water supplier is required to set water use targets based on its historical water use, the local climate, and locally implemented conservation programs. ("Urban water supplier" is defined in California Water Code Section 10617.) The statewide goal will be met by compiling the water reductions from each water supplier.

The legislation does not require a reduction in the total volume of water used in the urban sector. That is because other factors, such as changes in economics or population, will affect water use. Rather, the legislation requires a reduction in per-capita water consumption. Water consumption is calculated in gallons per capita per day.

As set out in the SB X7-7 legislation, and through the use of methodologies and criteria in *Methodologies for Calculating Baseline and Compliance Urban Per Capita Water Use* (California Department of Water Resources 2011), water suppliers:

- Must determine their baseline water use and target water uses for 2015 and 2020. Wholesale suppliers are not required to set targets but are directed to assist their retail suppliers in meeting the targets.
- Must report their gross water use during the final year of the reporting period (years 2015 and 2020). This is known as "Compliance Water Use."
- May revise their baseline water use calculations and change the method used to set their targets after submitting their 2010 urban water management plans.

Impact of the 20x2020 Plan

Projecting forward to the year 2020, with statewide population expected to be in the range of 44 million people, a decrease in per-capita water use of 20 percent would equate to an annual demand reduction of 2 million acre-feet of water.

The requirement that all urban retail water suppliers quantify per-capita baseline water use, set water use targets, and then show actual reductions in 2015 and 2020 has caused suppliers across California to pay particularly close attention to the effectiveness of their water conservation programs.

Box 3-2 Demand Hardening

Demand hardening is the assumed phenomenon by which customers find it more difficult to reduce demand because they have already implemented significant conservation measures.

Some water utilities have expressed concern that, because of the high degree of conservation already implemented in their districts, demand hardening may limit their ability to respond to drought and to meet 2020 water use reduction targets.

In response to this concern, the California Department of Water Resources and others sponsored the study *An Assessment of Demand Elasticity during Drought* to investigate how demand hardening may affect water agencies (Fryer 2013). Seven water agencies were selected for the study, four of which were in California. Each of these agencies had implemented significant demand management programs and had experienced drought events. Case studies of these agencies included investigation of water use histories; drought histories; water price trends; water conservation actions; local climate; demographics; economic patterns; and interviews with utility staff, community leaders, and residential customers. The project study period was 1970 through 2011.

Initial results from the study show that these water agencies, though highly saturated with conservation measures in recent years, did not appear to have greater difficulty meeting requested water use reductions. The study concluded that typical water utilities would only need to factor in demand hardening if planning for rationing in excess of 35 percent, and even at that point the effect of demand hardening was expected to be minor.

The study identified several areas that alleviated demand hardening:

- Landscape irrigation. It appears that a 50-percent reduction in landscape water use during serious droughts is possible. Turf irrigation can be cut back and is usually one of the first steps taken to save water. Low-water-use plants show a high potential to tolerate water stress. Water agencies may experience even greater landscape water savings depending on the level of landscape irrigation restrictions that are put into place.
- Behaviors. Water users typically meet or exceed conservation goals during drought and appear to be receptive to trying new conservation measures.
- Improving standards and technology. None of the agencies in the study had reached 100-percent saturation of conservation fixtures (low-flow faucets, toilets, etc.). And as new water-saving technologies reach the marketplace and efficiency standards continue to improve, 100-percent saturation will be an evolving target.
- Allocating conserved water to support new growth. When conserved water is allocated to new customers within an agency's service area, the water savings that may be required during a drought will be divided among a larger number of customers. The amount of required conservation for each customer will be less, effectively easing demand hardening.

Box 3-3 Landscape Irrigation Runoff

The photo below shows an example of irrigation runoff, frequently seen in landscapes throughout California.

Fortunately, many opportunities exist to improve efficiency in landscape irrigation. These include the use of evapotranspiration controllers, reduction of cool season turf, and education of water users.

The Residential Runoff Reduction Study (Municipal Water District of Orange County and Irvine Ranch Irrigation District 2004) demonstrated that a combination of evapotranspiration controllers and user education can greatly reduce dry season irrigation runoff.

In this study, dry season irrigation runoff was measured from 138 residential and non-residential landscapes. After the runoff was measured, the landscapes were retrofitted with evapotranspiration controllers, and the water users were educated in efficient irrigation practices. A second set of runoff measurements was taken after the retrofit and user education.

A comparison of the first and second measurements showed that irrigation runoff had been reduced by 50 percent by the installation of evapotranspiration controllers and user education.

PLACEHOLDER Photo A Irrigation Runoff

[For the public review draft, the draft photo follows this box.]

Photo A Irrigation Runoff

[photo to come]

Box 3-4 The Value of Landscape Water Budgets

Landscape water budgeting is a straightforward method for determining whether a site is receiving the correct amount of water to keep the plants healthy without wasting water. A water budget is calculated using local reference evapotranspiration data, an evapotranspiration adjustment factor, and the area (in square feet) of the irrigated landscape. The landscape area can be captured from landscape plans, by measuring the site, or through aerial imagery. Historically, obtaining the landscape area has been a challenge for water suppliers, especially when more than one meter may serve a parcel, but new tools and technology are becoming available that will simplify the process.

When the volume of water allowed in the water budget is compared with water use data, the irrigation manager can evaluate whether water use is on track and, if it is not, can make immediate changes to the irrigation schedule. Because weather conditions influence the water needs of plants, irrigation managers should assess compliance with the water budget weekly or at least monthly.

Water budgets are valuable communication tools. An irrigator that keeps a site within a water budget can show its customer the water savings and cost savings achieved when compared with historical use. Water suppliers can assign a water budget to an account and notify the customer when the budget is exceeded. Tiered rates based on water budgets send a pricing signal that discourages wasteful water use.

Box 3-5 Dedicated Water Meters: California Water Code Section 535

Since 2008, water suppliers must install a dedicated landscape meter on new non-residential water service with a landscape area of more than 5,000 square feet. The California Green Building Standards Code requires dedicated meters, metering devices, or sub-meters to facilitate water management on non-residential landscapes from 1,000 square feet up to 5,000 square feet.

Box 3-6 Case Study: City of Sacramento Advanced Metering Infrastructure

After installing advanced metering infrastructure (AMI) in more than 17,600 residences, the City of Sacramento reported the following successes during the two-year period of 2010-2011:

- 1,076 single family homes showed leak alerts.
- 75 percent of leaks were verified in the field.
- 367 million gallons of aggregate annual water loss were calculated through AMI reports.
- 236 million gallons of water were saved, which equates to 12.6 gallons per capita per day.

AMI can play a major component in helping the City of Sacramento reach the State mandate of a 20-percent per-capita reduction by 2020.

—2011 California Urban Water Conservation Council Advanced Metering Infrastructure Symposium, Sacramento

Box 3-7 Multi-Family Dwellings and Sub-Metering

Multi-family units are often served by a single water meter, and the water bill is included as a fixed part of a tenant's rent payment. This makes tracking individual tenants' water use virtually impossible and removes the consumers' incentive to conserve water in response to a high water bill.

When each dwelling unit within a multi-family property is individually metered, this is called sub-metering. A 2004 study (East Bay Municipal Utility District and Aquacraft 2004) found water savings of 15.3 percent when comparing sub-metered properties with rental properties that do not bill water separately from rent.

There are, however, numerous obstacles to capturing these savings, even in new buildings. Meter installation may lead to unacceptable pressure drop at some locations, and vertical plumbing layouts that supply water to each unit through multiple locations may make installation of traditional in-line water meters impractical. Important consumer protection issues must also be addressed if the interests of occupants dealing with water billing service companies are to be fully protected.

Sub-metering in multi-family dwellings could present an opportunity for significant water conservation in the future.

Box 3-8 Process Water

Process water is water used by industrial water users for producing a product or product content, or water used for research and development. Process water is highly specific to each industrial user.

Process water, within certain parameters, may be excluded from calculations of baselines and targets in order to avoid a disproportionate burden on another customer sector.

—California Code of Regulations, Title 23, Section 596

Box 3-9 California Prisons Reduced Annual Water Use by 21 Percent

By implementing a water conservation program, the California Department of Corrections and Rehabilitation (CDCR) achieved an annual water use reduction of 21 percent. The CDCR's water conservation program began in 2006, ramped up in 2008 in response to the drought declaration, and achieved a 21-percent reduction by 2009.

CDCR headquarters issued a document called *Best Management Practices Water Management & Conservation* that covered:

- Eliminating nonessential water use.
- Water-efficient landscaping and irrigation.
- Leak detection and repair.
- Laundries and vehicle washing.
- On-site water consumption surveys.

The CDCR enacted the following measures:

- Toilet flush meters were installed in nearly one-third of all adult institutions.
- Institutions report monthly water consumption to CDCR headquarters.
- Enacted low- or no-cost water conservation methods.

—*California Department of Corrections and Rehabilitation 2009*

Box 3-10 Consumption-Based Fixed Rates, City of Davis

Volumetric water rate structures provide a strong conservation incentive to customers. However, changes in customers' water use can cause a water supplier's revenue to vary, making it difficult to cover fixed costs.

Beginning in January 2015, the City of Davis will begin implementing an innovative rate structure, known as "consumption-based fixed rates." This structure introduces a method that provides revenue stability for the water agency, regardless of the volume of water sold, while also providing a conservation price signal to its customers.

This unique rate structure divides the agency's fixed costs proportionally among all its customers, based on the customers' peak use the previous year. Customers who have implemented conservation measures and reduced their water use will lower the fixed charge on their bill. The agency's variable costs are covered by including a volumetric charge on customers' bills.

More information about the City of Davis' rate structure can be found here: [To be determined].

Box 3-11 Successful Conservation Rate Structure: Irvine Ranch Water District

The rate structure at the Irvine Ranch Water District (IRWD) signals customers when they are exceeding their water budget and signals the IRWD about which customers are in need of attention.

The IRWD sets water budgets for each customer based on a variety of factors, such as the size of a landscape area, the weather, the number of residents, or the industrial or commercial business types. When a customer exceeds his or her water budget, the price per unit of water becomes more expensive. By taking these factors into consideration, the IRWD is able to customize the water budget for each customer and ensure a fair allocation.

The IRWD also charges a monthly fixed charge based upon meter size. The fixed charge covers all operating costs and related water use efficiency programs. The IRWD operates with a stable revenue stream despite variability in the volume of water sold.

Box 3-12 Reducing Irrigation Runoff Helps Local Waterways

Improving irrigation efficiency will prevent irrigation runoff, saving both water and energy and preventing the contamination of receiving waters by landscape pesticides, fertilizers, pet wastes, and sediment.

Sampling of the water quality in urban streams throughout California has found the universal presence of common landscape pesticides, such as diazinon, fipronil, chlorpyrifos, and bifenthrin among others. When excess irrigation water is applied, these pesticides, as well as herbicides, fertilizers, other nutrients, and pathogenic organisms are washed into the stormwater system and local watersheds. These contaminants are toxic to aquatic organisms.

Dry-season irrigation runoff can be prevented by irrigation system maintenance, proper irrigation scheduling, and landscape design. Irrigation scheduling should be appropriate for the site conditions, when factoring in slope, soil type, and the ability of the soil to absorb the water. Incorporation of rain gardens and vegetated swales into a landscape design will also retain runoff from irrigation and rainwater, reducing negative impacts on local waterways.

Box 3-13 Climate Change and Water Use Efficiency: The Energy-Water Nexus

California's energy and water resources are entwined. Energy is used to transport, pump, heat, cool, treat, and recycle water. And water is used to generate hydroelectricity and to cool power plants.

According to the report *California's Water-Energy Relationship* (California Energy Commission 2005), water-related energy use consumes about 19 percent of California's electricity, 88 billion gallons of diesel fuel, and 30 percent of non-power-plant natural gas. Urban water use comprises 58 percent of the total water-related energy consumption in the state.

When water is used efficiently, there is a corresponding savings in energy. Also, because most energy production creates greenhouse gases that contribute to climate change, water use efficiency is a method for mitigating climate change.

In 2004, California Urban Water Conservation Council members who implemented the council's best management practices reported a savings of 27 billion gallons of water. This significant water savings also saved more than 234 million kilowatt-hours of electricity and an estimated $200 million in energy costs.

Box 3-14 San Diego: Comparing Water Source Options

A 2010 study (Equinox Center 2010) comparing the marginal costs of seven alternative water solutions for San Diego concluded that conservation was the most favorable and least costly option.

Table A Cost per Acre-Foot by Water Source

Water source	Cost per acre-foot
Imported water	$875-$975
Surface water	$400-$800
Groundwater	$375-$1,100
Desalinated water	$1,800-$2,800
Recycled water	$1,200-$2,600
Conservation	$150-$1,000

These costs were determined for the San Diego area and would vary for each individual water agency.

Chapter 8. Water Transfers — Table of Contents

Chapter 8. Water Transfers

The California Water Code (CWC) defines a water transfer as a temporary or long-term change in the point of diversion, place of use, or purpose of use due to a transfer, sale, lease, or exchange of water or water rights. Temporary water transfers have a duration of one year or less (CWC Section 1725). Long-term water transfers have a duration of more than one year (CWC Section 1728).

Transfers can be between water districts that are neighboring or across the state, provided there is a means to convey or store the water. A water transfer can be a temporary or permanent sale of water or a water right by the water right holder, a lease of the right to use water from the water right holder, or a sale or lease of a contractual right to water supply. Water transfers can also take the form of long-term contracts for the purpose of improving long-term supply reliability. Generally, water is made available for transfer by five major methods:

- Transferring water from reservoir storage that would otherwise have been carried over to the following year. The expectation is that the reservoir will refill during subsequent wet seasons.
- Pumping groundwater (groundwater substitution) instead of using delivered surface water.
- Transferring previously banked groundwater either by directly pumping and transferring the banked groundwater or by pumping the banked groundwater for local use and transferring surface water that would have been used locally. (Groundwater banks consist of water that is “banked” during wet or above-average years. The water to be banked is provided by the entity that will receive the water in times of need. Although transfers or exchanges may be needed to get the water to the bank and from the bank to the water user, groundwater banks are not transfers in the typical sense. The water user stores water for future use; this is not a sale or lease of water rights. It is typical for fees to apply to the use of groundwater banks.)
- Reducing the existing consumptive use of water through crop idling or crop shifting to make water available.
- Water use efficiency measures that result in reduced seepage to saline sinks. Water that seeps to saline groundwater is irrecoverable. Any deep percolation, whether from canal seepage or from irrigated fields that would otherwise seep to unusable groundwater, can be transferred if the seepage is prevented. Thus, deep seepage conserved from lining a canal or by switching from flood irrigation to drip can be transferred.

Water exchanges are typically water delivered by one water user to another water user, with the receiving water user returning the water at a specified time or when the conditions of the parties’ agreement are met. Water exchanges can be strictly a return of water on a basis agreed upon by the participants or can include payment and the return of water. The water returned may or may not be an “even” exchange. Water can be returned on a one-for-one basis or by another arrangement (e.g., for each acre-foot [af] of water received, two af are returned).

Water transfers are sometimes seen as merely moving water from one beneficial use to another. However, in practice many water transfers become a form of flexible system reoperation linked to many other water management strategies, including surface water and groundwater storage, conjunctive management, conveyance efficiency, water use efficiency, water quality improvements, and planned crop shifting or crop idling for the specific purpose of transferring water. These linkages often result in increased beneficial use and reuse of water overall and are among the most valuable aspects of water transfers. Transfers also provide a flexible approach to distributing available supplies for environmental purposes.

Water Transfers in California

For a historical summary of water transfers in California, see *California Water Plan Update 2005* (California Department of Water Resources 2005).

Each year hundreds of water transfers occur in California. The majority of these transfers are between agricultural water users in the same basin (inter-basin transfers). Inter-basin transfers do not require review by other government agencies because there is no change to the permit provisions for place of use, manner of use, or point of diversion. These transfers are governed by the water rights held by the water district and are a matter of internal allocation adjustments by water district members.

Anecdotal evidence suggests that the percentage of water obtained through water transfers by agricultural buyers is increasing. Throughout the Central Valley, there has been a trend toward higher value crops replacing lower value annual crops. Some of the higher value crops include large acreage increases in permanent crops such as almonds. This trend has also occurred in the project service area of the West San Joaquin Division (westside) of the Central Valley Project (CVP). Water districts in the westside often participate in water markets to purchase supplemental water to meet water requirements of the permanent crops and account for much of the intra-basin agricultural water transfers. The westside is particularly susceptible to water shortages because many westside CVP contracts have a lower priority than other CVP contracts. Having lower priority for contract water means this region is typically the first and most severely affected by water shortages.

During 2005 and 2006, California experienced a relatively wet period, and water users had the opportunity to store some excess water in groundwater banks for future withdrawal. Many of these reserves were tapped in 2007 because of dry hydrology. In 2008, continuing dry conditions prompted the purchase of approximately 230,000 af of water from Northern California agriculture, specifically from various buyers south of the Sacramento-San Joaquin Delta (Delta).

In 2009, then-Gov. Arnold Schwarzenegger declared drought and tasked the California Department of Water Resources (DWR) with establishing the 2009 Drought Water Bank (Water Bank) to purchase water from willing sellers, which would be sold at cost to willing buyers. The amount of water requested for purchase from the Water Bank exceeded the approximately 80,000 af purchased for the buyers of the Water Bank. Several factors came to play in 2009 that limited the availability of Water Bank supplies. One significant factor was that high rice prices meant that rice growers were not willing to sell water at the price offered by the Water Bank.

In addition, as a result of operational constraints placed by the 2008 U.S. Fish and Wildlife Service and the 2009 National Marine Fisheries Service biological opinions for the coordinated operational criteria and plan (OCAP) of the CVP and the State Water Project (SWP), about half of the water made available by the idling of rice land could not be delivered to buyers in 2009, thus increasing the cost of transfer water to buyers beyond what they could pay or were willing to pay. In addition to the water transferred through the Water Bank, about 177,000 af were purchased by DWR from long-term water transfer programs already in place before the Water Bank, including the Lower Yuba River Accord (Yuba Accord).

An additional 23,100 af of water were transferred in 2009 south of the Delta, using only SWP conveyance facilities. Another nearly 400,000 af were reallocated among the CVP users but was not transferred across the Delta.

Operations restrictions, resulting from the biological opinions, affected the Water Bank's ability to purchase water (National Marine Fisheries Service, Southwest Regional Office, 2009; U.S. Fish and Wildlife Service 2008, 2009a, 2009b) originating from certain transfer proposals due to timing constraints in the movement of transfer water through the Delta. The biological opinions have resulted in restrictions on the export of combined CVP and SWP (Project) water at certain times of the year. Pumping restrictions have essentially limited pumping transfer water from the Delta to July through September. The result is that an increased export of Project supply has been shifted to the summer months, with the consequence that in years when SWP allocations are high (greater than 60 percent of the Table A supplies [see Glossary]), there is very limited to no capacity to convey water made available for transfer from upstream of the Delta to downstream. The net result of the biological opinions is to add additional uncertainty to water transfer transactions. As such, there is no guarantee that properly developed water transfer agreements can be executed and the transfers completed.

The pumping restrictions resulting from biological opinions have significantly affected the opportunities for cropland idling and cropland shifting water transfers. Transfer water from crop idling and crop shifting becomes available beginning in May. In some situations, particularly for Sacramento River diverters, required environmental releases make it impossible to hold transfer water in the Shasta Dam's reservoir for future delivery. This causes about 40 percent of the water made available for transfer to be undeliverable to the buyer in any given year. This circumstance causes the price of the transfer water from cropland idling and shifting to nearly double from the Sacramento River diverters. The water becomes so expensive, and so much cannot be transferred due to the operational constraints, that buyers are not willing to purchase the transfer water from crop idling or shifting from those diverters. Certain Feather River diverters, however, are able to store water from rice idling made available in May and June in Oroville Reservoir, or in the associated Thermalito complex, which can then be transferred during the July-September transfer period. The net result of the impact of the biological opinions on rice land idling for water transfers is that only about 25 percent of the potential rice acreage is able to participate in water transfers, as compared with the participating rice acreage before the biological opinions.

The Environmental Water Account (EWA) was established by the CALFED record of decision signed in August 2000 (CALFED Bay-Delta Program 2000). The EWA provided for enhancing environmental conditions for at-risk fish species, above and beyond regulatory requirements, through curtailment of pumping or reservoir releases (re-operations) at CVP and SWP facilities, with no net water cost to water users downstream of the Delta. The CVP and SWP water supplies forgone as a result of the re-operations were made up from EWA assets. From 2001 to 2006, EWA operational assets averaged 82,000 af, with a range of 0 to 150,000 af in a given year. The EWA negotiated an average of 60,000 af per year — termed as Component 1 water and typically stored in New Bullards Bar Reservoir — in the Yuba Accord (Yuba County Water Agency 2009). The Yuba Accord agreement runs to 2015, with a possible extension to 2025. According to provisions of the accord, the EWA's Yuba River water (Component 1 water) is only provided when the Delta is in balanced conditions. In rare instances, which occurred in 2006 and again in

2011, the Delta was in excess conditions throughout the summer period and into the fall, and the EWA's Yuba River water was carried over to a subsequent year when it could be made available and delivered to end users. In the foreseeable future, available Yuba River water will be used to offset SWP water lost from the recent Delta biological opinions.

Oversight of Water Transfers in California

Water transfers that involve changes in point of diversion, place of use, or purpose of use to a water right most often require the approval of the State Water Resources Control Board (SWRCB). Transfers that require the use of State, regional, or a local public agency's conveyance facilities require the owner thereof to determine that the transfers will not harm any other legal user of water, will not unreasonably affect fish and wildlife, and will not unreasonably affect the overall economy of the county from which the water is transferred (CWC Section 1810[d]). Strictly speaking, economic issues are typically only required to be evaluated in water transfers that seek to use DWR's water conveyance facilities or those of other State or local agencies. However, economic impacts associated with physical changes to the environment may require analysis under the California Environmental Quality Act (CEQA).

In addition, the California Water Code (CWC) specifies the requirements for changes in water right permits subject to the oversight of the SWRCB (post-1914 appropriated water; CWC Sections 1702, 1727, and 1736) and for water rights not subject to the SWRCB (pre-1914; CWC Section 1706). The CWC also specifies that DWR and other regional and local agencies must allow use of any unused conveyance capacity to a bona fide transferor of water (CWC Section 1810 et seq.).

To assist water projects that may require the use of Project facilities to complete a transfer, DWR and the U.S. Bureau of Reclamation (Project Agencies) have developed a draft technical information document. This document provides details that will assist transferors in developing the technical information that the two agencies will need to make their determinations under the CWC. This document is revised as needed and posted on DWR's website (California Department of Water Resources and U.S. Bureau of Reclamation, Mid-Pacific Region 2012).

Additionally, as of the preparation of *California Water Plan Update 2013*, the Delta Plan was prepared by the Delta Stewardship Council, pursuant to the Delta Reform Act. As drafted, the Delta Plan would contain enforceable regulatory policies that would apply to certain proposed plans, programs, and projects of public agencies that have been classified as "covered actions," in addition to a multiplicity of non-regulatory "recommendations." Public agencies that propose to undertake covered actions would be required to certify before the Delta Stewardship Council that the action is consistent with the Delta Plan. In 2016, temporary through-Delta water transfers may require a consistency determination with the Delta Plan. This would add another level of oversight for water transfers.

As the water transfer market has matured, the buyers and Northern California sellers have begun to develop mechanisms to better respond to concerns over potential transfer effects on local water users and the environment. Water transfer proposals are generally designed to avoid injuring any legal user of water; avoid unreasonably affecting fish, wildlife, or other instream beneficial uses; and avoid unreasonably affecting the overall economy or the environment of the county from which the water is being transferred. To further ensure that sustainable transfers are being developed, continued research and study of Northern California aquifers is necessary to better understand how those aquifers can safely supply water during times of drought. The studies must be a joint effort of State, federal, and local government, as well as involve other interested parties.

Local leadership and initiative are also needed to implement water transfers. Water transfers are typically proposed by local water agencies and can benefit from local community involvement in the development of these proposals. Some counties have passed local ordinances to regulate groundwater extraction for water transfer purposes. With adequate public notice, timely disclosure of proposals, and meaningful public participation, local communities can best assess their area’s water demands and supplies and determine whether there is potential for transferring water outside the local region.

Potential Benefits

For receiving areas, water transfers have the potential to improve economic stability and environmental conditions that would otherwise deteriorate with water scarcity. Sellers can use the compensation from transfers to fund beneficial activities, though there is no guarantee that benefits to the seller will benefit the source area as a whole. Compensation from most transfers involving agricultural water goes directly to the participating landowner, who may choose to reinvest in the farming business. In some cases, compensation goes to water districts, which can use the income to reduce water rates, improve facilities, or improve environmental conditions. For example, Western Canal Water District, in the northern Sacramento Valley, used proceeds from Water Bank sales to remove diversion dams and reconfigure its canals to reduce impacts on threatened spring-run salmon. Transfers by regional water agencies can provide additional resources to benefit the entire community. For example, the Yuba County Water Agency has used more than $10 million from the proceeds of water transfers over the past several years to fund needed flood control projects.

Potential Costs

The direct costs of completing a water transfer include more than just the price of water to the seller. Additional direct costs to the buyer include conveyance, storage, and treatment costs. Sale prices reflect the cost to make the water physically available for transfer and, in some cases, added monitoring or mitigation needed to protect the environment or other legal water users. The buyer typically arranges for transferred water to be conveyed to the area of use. Conveyance costs can be significant, and conveyance losses can lessen the amount of water actually delivered to the receiving area. In addition, there are also administrative costs of the conveyance agency in developing conveyance contracts, including staff time for ensuring compliance with statutory provisions regarding third-party impacts and the development of associated environmental review documents by the transfer proponents.

Another cost related to transferring water is carriage water. Carriage water is the extra water needed to carry a unit of water across the Delta to the pumping plants, while maintaining a constant salinity. For the Sacramento River, this has generally been about 20 percent of the transfer water and for the San Joaquin River about 10 percent. Carriage water is essentially a transaction cost that is negotiated between buyers and sellers.

Major Implementation Issues

Balanced Approach to Regulating Transfers

Some stakeholders assert that State laws and oversight of water transfers are not adequate to protect the environment, third parties, public trust resources, and broader social interests that may be affected by water transfers. This is particularly a concern for water transfers involving pre-1914 water rights, which are not subject to regulation by the SWRCB. Conversely, there is also concern that efforts to regulate water transfers more heavily may unnecessarily restrict many short-term, intraregional transfers that have multiple benefits during temporary supply shortages and that have little likelihood of direct or indirect impacts. The key issue is how to balance these concerns to allow water transfers to continue as a viable water management strategy while having mechanisms in place to minimize effects on others.

Stakeholders also have asserted that the regulatory requirements for completing water transfer agreements are burdensome. Much of the information requested by DWR and the U.S. Bureau of Reclamation from water transfer proponents is aimed at ensuring that the water being transferred is “a real water supply” (i.e., additional water made available to the hydrologic system for transfer by the supplier) and not someone else’s water. Some would contend that the present system is warranted and presents an adequate level of protection. For example, a water transfer involving pre-1914 water rights, while not subject to the review of the SWRCB, would require CEQA compliance if one of the parties were a public agency or would require the conveyance of a public agency to complete the transfer. Additionally, any project that would require the use of a public agency’s conveyance would require the agency that owns the conveyance to make certain determinations pursuant to CWC Section 1810(d) (no injury to other water users and no unreasonable impact on wildlife and the economy of the county from which the transfer originated).

In relation to these impacts, it should be noted that water is a resource fundamental to the physical and economic well-being of the local communities and areas in which it originates and is used. Although not readily apparent, far more water is appropriated in water rights permits for a given system than originally flows in the source system. This discrepancy in overappropriation of water rights can be explained by recognizing that water can be used and reused many times over. Impacts that may occur from various water management strategies are frequently hard to assess, in that most water systems are physically complex and uncertain and the uses in them are highly interdependent. For example, groundwater extraction, including that water used for water transfers involving groundwater substitution, may connect with and affect surface water flow. The extent of that impact would depend on when the extraction occurred and the magnitude of groundwater recharge by surface water replenishment. This could potentially affect water right holders with access to those surface waters. At this time, the analyses of these types of impacts are complex and replete with uncertainties. Future analytical tools may help to explain these complexities and reduce system uncertainties.

Environmental Concerns

Environmental consequences of transfers could occur in three places: the area from which water is transferred, the area through which water is conveyed, and the area to which water is transferred. Cumulative effects of short- and long-term transfers could have impacts on habitat, water quality, and wildlife caused by substituting groundwater for surface water; changing the location, timing, and quantity of surface diversions; reducing agricultural return flows to wildlife areas; or changing crop patterns through crop shifting or idling. For example, rice growing areas could have significant secondary benefits as wildlife habitat. Transfers that involve crop idling in these areas could either harm or benefit wildlife, depending on implementation. Transfers that involve increased groundwater pumping also raise concerns over groundwater overdraft and the long-term sustainability of groundwater resources. In addition, long-term water transfers that induce new urban development in the receiving area may have environmental impacts.

Using Temporary Water Transfers for Long-Term Demands

The potential for temporary water transfers to be used for long-term demands raises a couple concerns. One is that urban areas may use limited-duration transfers to accommodate additional development with water supplies that are not sustainable. Another is that agricultural users may rely on limited-duration transfers to supply permanent crops, such as orchards, that cannot be easily scaled back during droughts. Temporary water transfers are also used to supply the environment, such as refuge water, but these do not provide long-term supplies for this environmental use.

Economic Concerns

Short-term, out-of-county transfers created through extensive crop idling can reduce production and employment of both on-farm and secondary economic sectors, resulting in reduced tax revenues and increased costs for farmers who are not participating in the transfer. Extensive idling of crops that results in unemployment of low-wage laborers could be considered unfair treatment under the State's environmental justice policies (California Government Code Section 65040.12). In addition, reduced revenues could affect local governments disproportionately, with potential impacts on spending for a wide range of services provided by local government. Long-term transfers could result in similar impacts, even though the amount of fallowed land may be less. For long-term transfers, impacts on other elements of the local community (e.g., schools, businesses) may be more widespread and severe. Transfers of surface water that are replaced by increasing groundwater pumping may reduce groundwater levels and increase the pumping costs to other groundwater users, and may also contribute to groundwater overdraft.

State law generally requires that water transfers not unreasonably affect the overall economy of the county from which the water is transferred (referred to as the source area). However, there is potential for some economic disruption to source areas, depending on the source of transferred water, the amount of water transferred, and the duration of the transfer. The CWC provides for limiting the economic impacts on local communities by limiting the amount of water that can be provided by cropland idling by a water supplier to 20 percent of the water that would have been applied or stored (CWC Section 1745.05[b]), unless a hearing is conducted. While groundwater substitution still allows for a crop to be produced, cropland idling does not produce a crop, which may cause economic impacts on third parties. Although there is no evidence that recent water transfers have had long-term negative economic impacts on source areas, there is a concern that source areas could experience long-term economic impacts if transfers were to become more widespread. Water scarcity can also cause economic impacts, both where the shortage occurs and far beyond. Water transfers can help reduce water scarcity in areas receiving transfers, thereby helping to avoid job losses and secondary economic impacts in these areas.

Quantifying Uncertainties and Effects on Others

Transfers, especially those where water is moved long distances, are limited by several factors, including access to and physical capacity of conveyance systems; environmental and water quality regulations;

evaporation, evapotranspiration, and seepage along the flow path; linkages between surface water and groundwater movement and use; and other factors difficult to quantify or anticipate. For example, those water users who traditionally have relied on return flows from upstream diversions as a source of supply are concerned about being affected by changes in the timing and quantity of flows resulting from water transfers or water conservation measures. Quantifying the actual water savings from crop shifting and crop idling is particularly difficult because only the consumptive use by the crop is transferable in most cases. There is a risk that estimates of the water supply benefits from the transfer to the water system (estimates of "real water") will be inaccurate and that the transfers have unintended consequences to other water users, local economies, or the environment. A key challenge is to improve methods for quantifying these uncertainties and to include adequate monitoring and assurances when implementing water transfers. Monitoring is particularly critical for transfers that obtain water from crop idling, from crop shifting, from water use efficiency measures, or by increasing groundwater use. Information may be needed on historical and current land use and water use, groundwater levels, land subsidence, water quality, environmental conditions, and surface water flows.

Need for More Integrated Management of Water Resources

In California, authority is often shared among local, State, and federal agencies for managing different aspects of groundwater and surface water resources. Several examples are listed below.

- The SWRCB has jurisdiction for appropriative water rights dating from 1914, but disputes over appropriative water rights dating before 1914 are settled by the court system.
- The SWRCB has jurisdiction over groundwater quality, but disputes over groundwater use are settled by the court system.
- County groundwater ordinances and local agency groundwater management plans often only apply to a portion of the groundwater basin, and those with overlapping boundaries of responsibility do not necessarily have consistent management objectives.

Failure to integrate water management across jurisdictions makes it difficult to develop transfers with multiple benefits; provide for sustainable use of resources; identify and protect or mitigate potential impacts on third parties; and ensure protection of the legal rights of water users, the environment, and public trust resources.

Infrastructure and Operational Limits

The ability to optimize the benefits of water transfers depends on access to and the physical capacity of existing conveyance and storage facilities. For example, when export facilities in the Delta are already pumping at full capacity, transferable water cannot be moved. This occurred in 2003, when the Metropolitan Water District of Southern California (MWD) negotiated water transfers with growers in the Sacramento Valley but was unable to move water through the Delta, where the conveyance system was flowing full, or to store the water in Lake Oroville, which filled with late spring rain. As noted previously, the implementation of the biological opinions for the OCAP has also limited the period when water can be transferred across the Delta. This has affected Project water operations such that the exporting of Project water has now shifted to the water transfer period, which reduces available capacity for transfers.

The ability to convey water is also an important aspect of water transfers between the Imperial Irrigation District and the San Diego County Water Authority, which requires access to the Colorado River Aqueduct owned and operated by the MWD.

Climate Change

Water supply reliability faces increasing challenges, including impacts caused by changing climate. Increasing air temperatures will result in more precipitation falling as rain rather than as snow. This will shift the runoff timing, with higher runoff occurring in the winter and early spring and lower runoff in the summer and fall (California Natural Resources Agency 2009). The ability to capture this water for supply will be constrained in some cases by the need for flood protection. Warmer air temperatures will also increase the demands for both urban and agricultural users. Anticipated impacts from climate change also include more intense wet and dry periods (California Natural Resources Agency 2009). Longer, more frequent droughts will put additional demands on water supplies, and larger storm events could damage conveyance infrastructure. Water transfers can provide benefits in adapting to these expected changes in climate (preparing for unavoidable changes).

Adaptation

Water transfers can help improve regional resiliency to future climate changes by providing more operational flexibility and greater water supply reliability. However, the ability to transfer water may also be affected by these changes. Rising sea levels and reduced runoff in the summer and fall will contribute to greater salinity intrusion into the Delta, further limiting the ability to transfer water south of the Delta during the period when transfers can occur. While water transfers from north to south will potentially be limited, transfers between water users within a region could be an effective strategy for meeting local demands or responding to shortages associated with longer droughts or disruptions in deliveries.

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Within the SWP, water transfers are not typically a mitigation strategy. Water transferred from north to south via pumps is energy intensive. Transferred water replaced by groundwater pumping is another source of greenhouse gas emissions. If the transferred water is not replaced, then the land dries out and is left idle, releasing any sequestered carbon in the process. Water transfers could be considered a mitigation strategy only if the transfer eliminated the need to use a more energy-intensive source of water.

Recommendations

1. Because local government and water agencies have the lead role in developing and implementing water transfers, they should:
    - A. Implement monitoring programs that evaluate potential specific and cumulative impacts from transfers, provide assurances that unavoidable impacts are mitigated reasonably, and demonstrate that transfers comply with existing law.
    - B. Develop groundwater management plans to guide the implementation of water transfers that increase groundwater use or that could affect groundwater quality.
    - C. Evaluate and implement regional water management strategies to improve regional water supplies to meet municipal, agricultural, and environmental water demands and minimize the need to import water from other hydrologic regions.
    - D. Provide for community participation when identifying and responding to conflicts caused by transfers to which they are a party.

2. State and federal agencies, in addition to implementing State and federal law, should assist with resolving potential conflicts over water transfers when local government and water agencies are unable to do so and when there are overriding State or federal concerns.
3. State and federal agencies continue to gain consensus on how best to implement water transfers. The following actions are ongoing and should be continued and improved:
   A. Preparing programmatic and site-specific CEQA and National Environmental Policy Act (NEPA) documents and other technical assistance for interregional transfers.
   B. Developing and improving current computer modeling tools with the capacity to assess impacts of groundwater substitution transfers, including the effects on groundwater basins, surface water depletion, water quality, and subsidence.
   C. Conserving, protecting, and managing fish, wildlife, native plants, and habitats necessary for ensuring biologically sustainable populations of those species, in particular by the California Department of Fish and Wildlife (DFW, formerly known as the California Department of Fish and Game or DFG) as the trustee agency responsible for, and with jurisdiction over, those resources of the State (California Fish and Game Code Section 1802).
   D. Streamlining the approval process of State and federal agencies for water transfers where approvals are required, while protecting water rights, the environment, and local economic interests.
   E. Refining current methods to identify and quantify water savings for transfers using crop idling, crop shifting, and water use efficiency measures; and assessing the impacts of riceland idling on environmental resources, while using a collaborative process to evaluate a wide range of methods.
   F. Developing, with interested parties, acceptable ways to identify, lessen, and distribute economic impacts from transfers that use crop idling and crop shifting.
   G. Providing financial assistance for local and regional groundwater management activities that promote sustainable and coordinated use of surface water and groundwater. Seeking consensus among interested parties about the role of water transfers as a water management strategy while identifying and preventing or mitigating potential impacts on other water users, third parties, the environment, and public trust resources.
   H. Improving coordination and cooperation among local, State, and federal agencies with different responsibilities for surface water and groundwater management to facilitate sustainable transfers with multiple benefits, allow efficient use of agency resources, and promote easy access to information by the public.
   I. Developing water transfer policies that balance the ability of agriculture to provide water for transfers on a limited periodic basis to help with temporary water scarcity so that transfers do not destabilize agricultural productivity and economic benefits.

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Chapter 10. Desalination (Brackish and Sea Water)

Desalination, the removal of salts from saline waters, is one of the few options to augment California's water supply without competing with other inland freshwater uses, both human and environmental. The vast Pacific Ocean would even appear to be an endless supply, yet desalination faces cost and environmental challenges. The challenges are less with desalinating brackish groundwater — there are approximately 20 such sites around the state providing high-quality water to their customers. Even desalinating ocean water is already in the realm of feasibility, with eight operating seawater desalination facilities, including those taking ocean water from the sands under the ocean floor.

This situation highlights the diversity of California's water supply contexts and reinforces the fact that there are no absolutes in California water. Desalination is not a viable water supply for many water suppliers in the state, but for some it could make a significant contribution. How those California water suppliers move forward with implementing environmentally protective projects is a key issue facing multiple California communities.

Introduction

This Desalination Resource Management Strategy (Desal RMS) addresses key sea water and groundwater desalination issues and challenges. It also provides a framework for how California communities and water users may move forward with ocean and brackish water desalination. It

- Presents water desalination concepts and issues.
- Identifies where desalination is currently occurring and is being considered in California.
- Addresses issues related to a balanced approach to how desalination could support water sustainability in the state.
- Identifies recommendations for water suppliers and agencies to consider when evaluating desalination opportunities.

This Desal RMS focuses on presenting a strategy for sustainable desalting of surface and subsurface waters of the state for the principal purpose of meeting municipal drinking water demands. It discusses desalination technology, as well as the legal and institutional framework to consider when planning and implementing projects. The Desal RMS also addresses costs and environmental impact issues. Desalinating water for uses other than community water supply, such as large-scale agricultural, industrial, and mining activities, is not addressed in detail in this chapter but may be discussed briefly within the overall context of desalination technology or implementation of the practice.

Because of the complexity of desalination and the various ways desalination technologies are implemented in California, the Desal RMS presents brief summaries of key issues here. Additional detail about desalination technologies and issues are presented in Volume 4, *Reference Guide*.

Definition of Desalination

Desalination is the removal of salts from water to produce a water of lesser salinity than the source water. Other terms that are interchangeable with desalination include seawater or saline water conversion, desalting, demineralization, and desalinization. For consistency, "desalination" will be used in this chapter. Regardless of the terms chosen, the fundamental meaning is the removal of salt from a fluid.

Desalination can be used to reduce salinity in many types of water. The term ‘source water’ is used to identify the body of water from which water is taken for beneficial purposes. Source water for desalination can include ocean water, groundwater, and municipal wastewater. Desalination can be used to reduce salts in water or can produce water to drinking water standards. Desalinated water can be used for potable uses, such as municipal drinking water, or non-potable applications like agricultural irrigation or industrial processes.

Sustainability is a common theme of the California Water Plan (CWP) and an objective in the planning and management of water desalination. As used in this plan water sustainability is the dynamic state of water use and supply that meets today’s needs without compromising the long-term capacity of the natural and human aspects of the water to meet the needs of future generations.

Salt and Salinity

Many details about water chemistry, drinking water regulations, and the interactions between water bodies are beyond the scope of this chapter but play a significant role in setting State, regional and water quality and supply objectives and implementing a desalination strategy. Basic concepts and terms regarding salts and salinity of water are discussed below.

Salts occur naturally in the environment, but human activity often increases salinity in water and soil. Because of the negative impacts of salinity on human use or the water environment, salinity management is a critical resource management strategy. See Chapter 19, “Salt and Salinity Management” for additional information on this issue.

Description of Salts and Their Origin

The presence of certain impurities (e.g., minerals, elements, and chemical compounds) in water, especially at higher concentrations, affects the aesthetics or use of water. For example:

- Halite, the mineral commonly known as table salt or sodium chloride (NaCl), readily dissolves in water into ionic forms and is found objectionable to human taste even at low levels.
- Sodium, the element (Na), can affect soil properties damaging crops.
- Calcium carbonate (chemical compound, $CaCO_3$) deposits on household fixtures and industrial equipment causing damage or increasing maintenance.

When solid substances mix with water or other liquids, they may separate (dissolve) into two parts, one with a positive charge (such as sodium or calcium) and one with a negative charge (such as chloride or bicarbonate). This form of a dissolved solid is termed an ionic substance. The majority of dissolved solids in raw and finished municipal water supply sources, fresh or saline, are ionic inorganic substances such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, bromide, and nitrate. These dissolved ionic elements or compounds are known collectively as “salt”.

The principal source of salt in the oceans and brackish waters is from the land. The salts are leached out a bit at a time as water flows over and through the land during each hydrological cycle. Over the millenniums, the oceans, seas, and other saline bodies of water have become salty through the action of fresh water interacting with rocks containing minerals, like the sodium chloride compound, to make them salty. After water evaporates from the surface of a saline water body, the salt is left behind further increasing the salinity. The oceans have developed a noticeably salty taste. The ocean and some inland low-lying bodies of water without drainage accumulate salts, and thus are called “salt sinks.” Salt sinks have traditionally not been used for municipal water supplies in California.

Salinity Measurements

The saltiness of water is referred to as its salinity. "Salinity" is generally defined as the amount of salt dissolved in a given unit volume of water. It is variously measured in units of electrical conductivity (EC), total dissolved solids (TDS), practical salinity units (PSU), or other units depending on the scientific discipline of the person doing the measuring and the purpose of the study or monitoring program.

The unit of measure most often used for TDS is milligrams per liter, mg/l. Since one liter of pure water weighs one million milligrams at a referenced temperature, TDS is expressed as parts per million, ppm, parts per thousand, ppt, as well as percent salinity. The generally accepted value for salinity of open sea water is a TDS of 35,000 mg/l or ppm, also expressed as 35 parts per thousand (ppt) TDS or 3.5 percent salinity (3.5 percent salt). TDS is one of the bases for federal and State standards for how much dissolved material is in a water supply.

While TDS is often the measurement of salinity, it should be understood that the TDS measurement includes other dissolved chemicals besides salts, including metals such as copper and iron and elements like boron. Also, sodium chloride is often the most common and highest salt ion concentration in water and is the salt most frequently equated to salinity. While sodium chloride may be the most common salt, many other dissolved salts in ionic form are found in natural waters.

There are a number of ways to measure saltiness in water or soil with each having its role in various sciences (e.g., oceanography, hydrology, and geology). The most used metrics are shown in Table 10-1.

PLACEHOLDER Table10-1 Measurements of Salinity

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Degrees of Salinity

There is no fixed delineation between "fresh" and "brackish" water; as such and for this chapter, a TDS concentration value of 1000 mg/l or 0.1 percent salinity is used for the dividing line, which is consistent with many references.

The term "brackish", in general, refers to water that has more salinity than fresh water but less than sea water. There also is no rigid delineation between brackish water and seawater; however, 30,000 mg/l or 3 percent salinity will be used for the purposes of this chapter to make a general delineation between brackish and sea water.

The average salinity of seawater is generally taken to be 35,000 ppm TDS or 3.5 percent. The range of salinity in ocean water varies and for the purposes of this chapter the range is established from 30,000 mg/l to 50,000 mg/l, which can include inland seas, such as the Salton Sea with a rising salinity currently near 44,000 mg/l TDS.

The term "brine" is a general term having different meanings in industry, water management, and even household cooking. Brine may refer to any naturally occurring water with a salinity higher than seawater or to reject water from a desalination facility. In many food preserving processes, brines are used of varying salinity to achieve a specific purpose. For the Desal-RMS, the term "brine" refers to the high salinity reject water normally associated with the treatment processes used to remove salts. While the reject water from a desalination facility using reverse osmosis technology may be referred to as "brine", it may have concentrations as low as 4,000 mg/l TDS, such as in the case of desalting brackish groundwater. Thus, the term brine remains relative to the context used. Natural brines, like those found under the Salton Sea and other geothermally active locations in the state, are usually hot with salinities much higher than seawater. The Salton Sea natural brines are approximately 280,000 mg/l TDS or 8 times that of average surface seawater.

Table10-2 below provides a few general salinity ranges in TDS for water quality classification purposes.

PLACEHOLDER Table10-2 General Water Salinity Levels Based on Total Dissolved Solids (TDS)

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Fresh, brackish, and sea are qualitative terms that do not necessarily specify an origin or the exact environment from which a water withdrawal is made. There is often a common inference that the term "brackish" refers to groundwater and that "seawater" refers to surface water from the sea. Water characterized by the terms fresh, brackish, or sea may be withdrawn from surface and subsurface locations. Because "brackish" and "seawater" are not locations but are better descriptors or degrees of salinity, there should be no inferences made associating "brackish" water to subsurface (groundwater) and "seawater" with open or surface water in discussions concerning desalination or saline waters. The subtitle of this chapter denotes "Brackish and Sea Water" as the two main types of saline water available in the state requiring desalination regardless of whether they are surface or groundwater in origin.

Sources of Water for Desalination in California

General

This section considers water sources suitable for municipal drinking water supply using desalination technologies. While desalination technologies also have the potential to treat municipal wastewater suitably for direct potable reuse, that topic is not covered in this chapter but in Chapter 12, "Recycled Municipal Water."

Typically, raw water sources must meet basic municipal water supply development criteria for quality and quantity. Municipal source waters should be capable of providing an adequate and sustainable amount of water for an intended beneficial use. Potential sources include oceans, bays, rivers, lakes, and groundwater aquifers. The determination of the safe yield from a water body is necessary for desalination as well as many other types of water supply projects. The ocean and other saline open water environments afford the greatest safe yield potential for desalination water supply projects in California.

Typical water source types used for municipal water supplies throughout California, including those requiring desalting to provide a fresh drinking water, together with a typical treatment facility are shown in Figure 10-1.

Figure 10-1 Basic Municipal Drinking Water Facility and Source Waters in California

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

As a general rule most water sources with a TDS concentration higher than 1,000 mg/l are termed brackish and will need desalination treatment or blending with fresher water to meet municipal drinking water quality criteria.

Source Water Classifications

Differences between sources of water suitable for desalination relatively affect cost, environmental impacts, greenhouse gas emissions, and other feasibility factors. For this and other reasons, it is important to classify water by source and quality for further discussion.

Water bodies are generally classified as either surface or subsurface (groundwater). Although, the term "surface water" is often used to denote only fresh surface water. In this chapter, the term "surface water" does not denote water quality such as the salt content and includes saline waters such as the ocean, marine bays, or other saline water bodies in addition to the traditional fresh water lakes, rivers, wetlands, and other surface water bodies. Water bodies are generally classified as either surface or subsurface (groundwater). Some water sources are further typed with distinctions to improve delineation.

For purposes this chapter, the following classifications of source waters are made:

- Open sea water (surface).
- Open fresh water (surface).
- Groundwater (subsurface).
- Groundwater (subsurface) under the direct and natural influence of a surface water such as the sea
- Confined groundwater with limited natural reoccurring recharge from annual precipitation.
- Brackish surface water such as an enclosed bay or estuary, which may be fresh or saline dominant depending on a mixing zone or seasonal variations.

In addition to surface and subsurface or ground water classification, there are qualitative salinity descriptions such as fresh, semi-fresh, brackish and sea. Because the term "sea" can refer to both location and water quality; we are compelled to add more adjectives providing a more precise description of a water body such as open and inland as in the "open sea" or the "inland sea". (California's Salton Sea, an inland sea, is an example of a surface water body with a higher salt content than found in the open ocean.

PLACEHOLDER Figure 10-2 General Distinctions for Location

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

The general distinctions for location and relative quality given in Fig. 10-2 above and additional terms added as necessary will help describe the general distribution of water relative to depth and source in the state.

Describing a water body using the terms "fresh", "brackish", "sea", or other characterizes the degree of salinity or freshness of source water and it depends the context. Table 10-2 provides a convenient gradation using these common terms as they are used in this chapter.

Table 10-2 Gradation Common Terms

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

It is convenient to type brackish groundwater into main categories related to the natural hydrological cycle, replenishment, and hydrogeological interconnectedness with fresh and saline waters:

- Type I – Groundwater is replenished by freshwater sources or other brackish groundwater. There is little to no interconnectedness to a seawater source of replenishment. Brackish groundwater extractions may adversely impact fresh groundwater supplies.

- Type II-- Groundwater is replenished by both seawater and freshwater sources. There is a connection between fresh water and seawater sources. The interface between these sources is subject to change based on the hydrologic cycle, groundwater extractions, and seawater elevation. Brackish groundwater extractions may adversely impact fresh groundwater supplies.
- Type III-- Groundwater is replenished by a seawater source with no connection to freshwater sources. Brackish groundwater extractions in this environment are not likely to adversely impact natural freshwater supplies, surface or groundwater. Further distinctions may be made as to the degree of the open seawater direct-influence.

Subsurface Water

This section of the chapter provides information about issues that can occur from extraction of water that is present below the land surface, groundwater, for municipal drinking water purposes.

When considering a water source for water supply it is imperative to determine the safe yield of the water body. Safe yield of a groundwater basin or aquifer system is defined as the amount of water that can be withdrawn from it without producing an undesirable effect (Todd, 1959). The safe yield should not deplete or overdraft the water reserves. The yield should not cause intrusion of lower quality water into the aquifer. This lower quality water includes seawater, polluted, as well as waters of a lesser quality. Additionally, the safe yield should not cause land subsidence. Surface water bodies such as streams or lakes connected to aquifers might become depleted through the extraction of groundwater and infringe on water rights. Note that anything in excess of the safe yield is an overdraft.

When the safe yield of a subsurface water source is limited, it may be best to reserve the water for emergencies such as droughts.

Seawater intrusion is the subsurface flow of seawater into a subsurface water body. The higher density of seawater allows it to flow beneath the fresher water and move inland. Extraction exacerbates the inland flow by lowering the water level and reducing the overlaying pressure, allowing seawater to flow further inland. Because seawater has very high salt content, the influx causes a degradation of water quality. This results in higher water treatment costs. Brackish groundwater extraction near the coast could exacerbate seawater intrusion.

Because aquifers are often interconnected to surface water bodies such as streams or lakes, groundwater extraction affects these surface water sources. Some of these ecological impacts include surface water depletion, loss of the surface water habitat, which affect fisheries, wildlife, and plants, and land subsidence, among others. The known ecological impacts of groundwater overdraft in California include diminished stream flow and lake levels, damaged vegetation, and corresponding effects on fish and migratory birds.

A notable distinction between groundwater and surface water is that unlike seawater and its corresponding marine environment, the public does not directly associate groundwater with an important ecological habitat; there are no groundwater species included on the federal endangered species list to date. This belief engenders the claim that desalination of brackish groundwater occurs with brine disposal as the only major ecological or environmental impediment other than GHG emissions associated with energy consumption. The interaction of groundwater with surface water needs to be considered.

Surface Water

Since seawater is the major source of surface waters for purposes of desalination this section will focus on this water source. This supply alternative is unique in that seawater is not dependant on the hydrologic cycle and can produce fresh water reliably even with the climate change projected droughts (NAP, 2008). At the same time, the sea provides vast resources beyond just a possible raw water source for meeting our freshwater demands. This section will focus on presenting the factors, which set the seawater environment apart from the brackish groundwater.

Seawater contains an array of nutrients supporting plankton blooms and is the broth for much of the marine environment's food web. The marine waterscape includes forests of kelps where young and mature fish and seals dwell along with crabs, snails, and other species of mammals, fish, and invertebrates.

While 35,000 ppm TDS is the average salinity of open sea water, scientists know that salinity naturally varies throughout the open oceans and seas and plays a role in global climate. Some marine life depends on a narrow range of salinity fluctuations. Marine biologists are trying to understand just how sensitive certain marine environments, such as the benthic regions on the ocean floor, are to changes in salinity levels. Since the discharge of brine could affect salinity levels, this could increase the mortality of the marine life, an undesirable effect.

Note that the safe yield of a surface water body is the annual amount of water that can be removed sustainably without interfering with water rights. Because of the great volume of water in the oceans, ocean and other saline open water environments afford the greatest safe yield potential for desalination water supply projects in California. However, local physical constraints and environmental concerns limit the potential safe yield.

Although the oceans may be said to be inexhaustible, the term should be used with caution. The sustainable extraction of seawater for desalination to meet municipal freshwater demand is dependent upon safeguarding the seawater environment; the seawater environment and the marine life that lives in it is not "inexhaustible".

Desalination as a Water Treatment Technology

Introduction

Desalination as already defined is the removal of salts from water to provide a water of lesser salinity than the source water. Salt is but one of many contaminants found in source water used for municipal drinking water. There are many types of processes using various water treatment technologies to remove these contaminants. More information may be found on drinking water treatment in California in Chapter 15 of CWP.

Aside from the treatment technology to remove the salts, a desalination project must include other elements to convey and additionally treat the source water and to deliver the finished water to customers. Figure 10-3 depicts key elements of a desalination system as will be discussed later in this section.

PLACEHOLDER Figure 10-3 General Desalination System Schematic

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Not all elements, as shown in Fig. 10-3, are necessary for all desalination systems. The "Pretreatment", "Post Treatment", "Blending", "Solids Disposal", and "Concentrate" elements do not occur in all desalination systems while the "Raw Water", "Intakes", "Desalination", "Finished Water", and "Distribution" elements are always part of full-scale desalination systems. The elements of "Raw Water" and "Distribution" in this schematic are included to emphasize that where the water comes from and where it ends up are part of a desalination system as they affect feasibility, design, and environmental impacts.

Other common terms may be used when discussing treatment processes. Here are a few: “component” is widely used instead of “element” in many textbooks, “product water” and “permeate” may be used instead of “finished water”, “feedwater” and “influent” are often used instead of “raw water”.

This section will (1) provide an overview of the types of desalination technologies available and under research, (2) give some detail on the desalination technology known as reverse osmosis (RO), and (3) present the various elements of a municipal drinking water system using the RO technology for desalination.

Overview of Types of Desalination Technologies

The processes, technologies, and methods used to achieve a desired level of salt removal in water include a wide range of products and systems. This overview provides general information on both established and new or emerging desalination technologies.

Table 10-3 provides a list of desalination technologies and their general application. It is convenient to place desalination technologies or processes into three main categories: (1) thermal (2) membrane separation, and (3) all others.

Table 10-3 General Desalination Technology List

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Thermal Distillation Processes

The oldest desalination process is distillation, which has been used for over 2000 years. Thermal desalination processes render safe and reliable water from almost any raw water source including fresh, brackish, and sea water sources. The basic concept behind distillation is that by heating an aqueous solution one can generate water vapor. The water vapor contains almost none of the contaminants, like the salt or other materials originally found in the source water. If the water vapor is directed toward a cool surface, it can be condensed to liquid water containing very little of the original source water contaminants. This condensed water vapor is the product water of the desalination processes using the thermal distillation principles. The salts and other contaminants accumulated in this process are managed as solid waste. These solid wastes may have value in the commercial and industrial marketplace.

Most large scale thermal distillation facilities are coupled with power plants that use steam turbines to generate electricity. Waste heat (i.e., energy) from the cooling of the power generation system can be used in the distillation process to reap benefits of a “cogeneration” approach to produce drinking water and electric power in the same complex. No municipal drinking water in California is produced with a thermal distillation process. Many of the large scale facilities using thermal processes at the municipal or industrial level are in Middle Eastern countries.

Two of the most widely used thermal processes for seawater desalination are Multi-Stage Flash evaporation (MSF) and Multi Effect Distillation (MED). The most widely used distillation process is Multi-Stage Flash evaporation (MSF). Among the advantages of MSF and other distillation processes is that the composition of feedwater has an almost negligible affect on the energy required to produce a volume of product water. The processes deliver exceptionally high purity water (less than 25 mg/l TDS) and have been successfully operated in very large sizes. Among the disadvantages are the high capital cost and the requirement for a large input of heat. Thermal desalination processes work well at the scale related to the energy readily available through cogeneration or other natural heat sources (e.g., geothermal heat source).

At least one new thermal process concept has been proposed for possible use in California that claims to eliminate brine wastewater discharge back into the environment, operates with higher efficiencies than other distillation processes, and management of solid waste includes recycling mineral recovery products into the industrial complex (United States Patent 8,946,787).

Membrane Separation and Reverse Osmosis Technologies

Many ways have been developed to separate salt from water. Membrane separation technologies are most commonly used for desalination. A membrane for this purpose is a thin, film-like material that separates two fluids. It is semi-permeable, allowing some particles or chemicals to pass through, but not others. The objective is to allow water to pass through the pores in the membrane and prevent the passage of other substances. In reality, what is filtered out depends on the size of the pores and the type of material used for a membrane. Reverse osmosis (RO) membranes are most effective for salt removal, but no membranes result in pure water. Categories of membranes with increasingly smaller pores are microfiltration, ultrafiltration, nanofiltration and RO. Examples of the substances removed by membranes are illustrated in Figure 10-4. A brief description of membranes is also given in Table 10-4.

PLACEHOLDER Figure 10-4 The Filtration Spectrum

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

[PLACEHOLDER graphic Taken from Advanced Membrane Technologies, Stanford University, May 07, 2008, Mark Wilf, Ph.D. Tetra Tech, need permission or need to develop our own. Many of these types of charts exist. Filename Membrane_types.pdf]

Table 10-4 Brief Description of Membranes

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

A schematic representation of the membrane process is shown in Figure 10-3. The product water is the permeate, which is desalinated water in the case of RO. The reject water is brine in the case of RO. Brine management is a key issue that is discussed later in this chapter. RO membranes typically come in the form of rolls called cartridges. The membrane sheets are sandwiched between spacers to allow feedwater to enter one side of the membrane and permeate water to pass through and leave the other side. The salts are left behind on the feedwater side of the membrane and build up in concentration, becoming brine. All assembly of RO cartridges look like the view in Figure 10-5.

In general, an energy input is required to use membrane separation. High pressures are needed to get water molecules to pass through the membrane at fast enough rates for functional municipal scale applications and to overcome the inherent properties of the membrane. The amount of energy required, generally, increases as the particle size decreases and salt concentrations increase. Energy is a major factor in desalination, especially seawater desalination, and is discussed further in the issues section of this chapter.

Among the various membrane separation technologies listed in Table 10-3, reverse osmosis (RO) has matured rapidly over the last few decades and has become the process of choice for many desalination projects. In the USA, it has become the most economic process and is now widely utilized in the Southeast, Southwest, and West to provide an alternate source of supply derived from saline surface and groundwater. Because of its current prevalent position in the desalination arena in California, RO will be the focus of further discussion of desalination in this chapter.

Basic Elements of a Desalination System

Each of the elements of a desalination system, as shown in Figure 10-3, is discussed in this section. There are distinctions between systems using surface sources (mainly seawater) and subsurface sources (brackish groundwater or groundwater under the direct influence of surface seawater). The differences will be described. Figure 10-3 is a simplification of a desalination system. There are systems that omit one or more of these elements, arrange the elements in a different order, or combine elements into various combinations representing one component of a single facility.

Raw Water

The raw water element as the source water for desalination, also referred to as feedwater. Encompassed in this element is not only the water itself but also the geophysical characteristics of the environment containing the water. The raw water characteristics affect the capability of a particular location to serve as a water source, the design of facilities to accomplish water extraction, and the protection needed for the environment and the raw water for long term sustainability.

The typical raw water factors for surface water intakes that must be considered include oceanographic conditions, limnology of fresh water bodies, hydrogeology, episodic water quality changes, benthic topography, pollution, and adverse impacts to aquatic species. A surface water source supports an aquatic ecology that is especially susceptible to damage caused by water intakes. Design features can minimize those effects, as described in the next section, but mitigation measures may be needed to compensate for unavoidable impacts.

Typical raw water factors to consider for subsurface water intakes include water quality, long term safe aquifer yield, interaction with surface water, and seawater intrusion impacts. Subsurface intakes, under the ocean floor or at inland near shore locations, can be a means of using seawater while avoiding surface water intake effects on aquatic organisms. However, they can also cause seawater intrusion into or depletion of inland freshwater aquifers.

Intake

The intake element consists of the entrance structure where raw water is withdrawn, a pipeline to convey the water to the desalination and other water treatment facilities, and pumps to lift and move the water. It is common to include a pretreatment element, a screen, at the water intake to avoid sucking in aquatic organisms and undesirable suspended debris or, in the case of groundwater wells, sand or other particles. Discussion of intakes will include these associated screens.

For surface water intakes, particularly for ocean water, impingement and entrainment of organisms are key concerns. Impingement occurs when organisms sufficiently large to avoid going through the intake screens are trapped against the screens by the force of the flowing source water. Entrainment occurs when aquatic organisms enter the desalination plant intake, are drawn into the intake system, and pass through to the treatment facilities. Impingement typically involves adult organisms (fish, crabs, etc.) that are large enough to actually be retained by the intake screens, while entrainment mainly affects aquatic species small enough to pass through the particular size and shape of intake screen.

Intake systems may require under-water activities including excavation, dredging, embedment, pipe laying and anchoring. The construction impacts might be minimized by sharing intakes with other facilities, such as power plants, or using existing infrastructure no longer needed for its original use.

Figure 10 –X illustrate examples of screened intake structures currently used in seawater desalination systems. **[One or more of these figures will be used.]**

Pretreatment

Desalination treatment technologies, especially RO, require a feed water minimum quality to avoid facility damage, corrosion, membrane fouling (clogging), impaired performance, or excessive maintenance. Raw water often needs to be conditioned through pretreatment to provide a water suitable for the desalination element. Intake screens are often the first pretreatment component to remove weeds, algae, fish, shells, and other larger particles. Certain source waters are subject to contamination by natural toxins generated by algal blooms (red tides), wastewater discharges (point and non-point), oil and hydrocarbon residues or spills, urban runoff, and agricultural pollution such as animal wastes, fertilizers and pesticides. Pretreatment ahead of RO membranes often includes disinfection, biocide, and other chemical additives to control biological growth, scaling, and corrosion effects. Pretreatment may also include other membranes, such as microfiltration, to improve the efficiency of RO.

Subsurface intakes have another form of pretreatment — the filtering effect on water flowing through sediments in the ground. To avoid impingement and entrainment effects on aquatic life, subsurface intakes from wells under the ocean floor can be used if the right geologic conditions exist. Figure 10-6 Intake 2 & 4 provides a cross-section view of a typical engineered gravel-packed well.

Figure 10-6 Cross-section View of a Typical Engineered Gravel-packed Well

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Blending

Blending may occur before or after the desalination treatment element. The water used for blending may be another raw water source or potable fresh water. The purposes for blending include improving either the desalination operation or the aesthetics of the finished water for customer acceptance.

Desalination

The function of the desalination treatment element is the removal of salts and other contaminants. It is the core of a desalination system. RO is the most common desalination technology for producing potable water. This element also includes pumps to force water through the RO membrane and energy recovery devices. Because of the high pressure needed for RO, desalination treatment is the most energy intensive element of a desalination system, even with energy recovery devices. While RO is used to treat both brackish water and seawater, because of the lower salt content of brackish water, the energy needed for brackish water is much less than for seawater treatment. Energy needs are discussed later in this chapter.

There are two products from RO treatment, the permeate (desalted water) and reject brine (ultra salty wastewater).

Post Treatment

Permeate water leaving the RO process can be acidic and has little hardness. It can be corrosive to pipes and have an unnatural taste and feel. Post treatment may include addition of chemicals to produce an acceptable water from the consumer perspective. Blending with another source of water is another way of adjusting the quality of water. Post Treatment includes providing the necessary disinfection treatments to produce a finished water.

Finished Water

The finished water element has been included in the discussion to show the end product of the treatment elements involved in an RO facility. At this stage, the water may be served to customers through the distribution system.

Distribution

The distribution element consists of the facilities needed to convey the finished water to the consumer. The facilities are pipelines, pumps, and storage tanks. Most communities considering desalination already have a water distribution to deliver their existing sources of water. When a new desalination treatment plant is constructed, a pipeline is needed to connect the desalination treatment facility to the existing distribution system. If the source of brackish or seawater is far from the existing distribution system, the connecting pipeline and associated pumps or tanks could be expensive. If the existing distribution system is not designed to receive a large new flow of water, modifications to the existing system may be necessary.

Solids Disposal

[Under development, not available at this time]

Concentrate Management (reject, brine, waste)

[Under development, not available at this time]

Desalination in California

Desalinated water currently is one of California's lowest volume potable water supplies. However, desalination of groundwater and ocean water is being considered more frequently as water supplies become constrained, more local supplies are sought, and technologies improve and become more cost-effective. Additionally, with submittal of their 2010 urban water management plans and the IRWM State funding program, California water suppliers are now required to evaluate desalination of brackish groundwater and seawater as a method to meet their water resource management goals and objectives.

For most California water suppliers, desalination is neither practical because a brackish or saline water source is not nearby nor is it economically feasible because more cost-effective water supplies are available. However, desalination is increasingly being considered a supply worth evaluating, particularly where current water supplies are strained. Some of these evaluations have become high-profile and vociferous, but they have resulted in very important water supply reliability and sustainability discussions.

There are approximately 840 miles of general coastline and about 3,427 miles of tidal shoreline in California.

History of Desalination in California

The first major facilities involving desalination came online in the 1960s, primarily to support cooling processes at power plants such as PG&E's Morro Bay and Moss Landing facilities. Since then, desalinated sea water has been successfully integrated into industrial and non-potable uses at multiple coastal sites.

In the 1960s, it was envisioned that desalination could play an increasing role in California's water supply and power generation needs. In the 1960 transmittal letter for DWR Bulletin 93 entitled "Saline Water Demineralization and Nuclear Energy in The California Water Plan", DWR Director Harvey O. Banks wrote to Governor Edmund G. Brown and members of the Legislature of the State of California:

> "Although no saline water demineralization technique yet developed can compete with the costs of large scale development of natural sources of water in California, it is probable that saline water conversion plants will have a definite place in the water program. The Department of Water Resources will continue to take a definite and continuing interest in those areas of research and development that may have promise of eventually producing low cost converted water."

Desalination technologies were extensively tested in California in the late 1950s and early 1960s to address water supply issues. Experiments and pilots testing of different technologies and projects were conducted using both ocean and groundwater source water (DWR 1960 and 1962). Desalination was also considered as part of the San Joaquin Valley Drainage investigation.

Coalinga was the site of the first operational brackish groundwater desalination facility. It operated from 1959 to the early 1960s, reducing groundwater salinity from 2,100-2,400 to under 500 mg/L (DWR 134-62). Demand increased to higher than the facility's capacity, so the world's first commercial reverse osmosis plant was built (UCLA website http://www.engineer.ucla.edu/explore/history/major-research-highlights/first-demonstration-of-reverse-osmosis) and operated between 1965 and 1969 (Davis et al 1981). Coalinga now receives surface water from the US Bureau of Reclamation.

The first ocean desalination facility in San Diego was constructed in 1962 but intake issues involving kelp and sea grass caused operational challenges (DWR 134-62). The US Navy also began early California desalination operations and research at Port Hueneme (DWR 134-62).

In addition to Morro Bay and Moss Landing, desalination for power plant operation was implemented in 1960 at Southern California Edison Mandalay steam station (now Reliant Energy Mandalay), in Ventura County and later at the Contra Costa Power Plant on the San Joaquin River in Contra Costa County (DWR 134-62).

In the 1970s and 1980s, DWR tested the feasibility of desalinating agricultural drain water to address San Joaquin Valley drainage issues. Reverse osmosis testing facilities were constructed in Firebaugh and Los Banos. These projects assessed biofouling issues and implementation requirements. Ultimately, because of Kesterson drainage issues, the project was discontinued in 1989.

In the 1970s and 1980s, several communities completed potable water desalination facilities, but for various reasons, each of those projects only operated briefly. Decommissioned or non-operational facilities are or were in San Simeon and Santa Barbara. Marina Coast Water District has a standby desalination facility. Reasons cited for ceasing desalination include operational expense and challenges, availability of less expensive supply, and end-of-drought conditions.

San Simeon State Park received desalinated water for a brief time in the early 1990s. An existing desalination facility was moved from the Central Valley to San Simeon to support park water supply shortages. The facility has since been removed.

In the 1990s, several communities constructed brackish groundwater desalination facilities. The City of Tustin completed its groundwater desalter in 1989. Over a dozen other facilities were constructed and began operation by the end of the decade. These facilities were primarily located in the near-coastal and inland areas of the greater Los Angeles.

Present/Current Desalinated Water Use in California

Desalination is currently an important water supply for areas throughout California. Existing projects are identified in Table 10-6 and are shown in Figure 10-5. Desalination of brackish groundwater and sea water are discussed separately below.

Current Brackish Groundwater Desalination

Groundwater desalting plants are generally designed to reclaim groundwater of impaired use and are located in urban areas from the San Francisco Bay Area to San Diego. Currently, there are at least 20 operating groundwater desalting plants, 19 of which are located in southern California. Plant capacities range from 500,000 gallons to 10 million gallons per day (mgd) (11,200 AFY). Up to an additional 20 plant expansions or new facilities are planned to be constructed before 2040.

Inflow groundwater quality ranges significantly depending on the project. The primary constituent targeted for removal by these projects is usually TDS but nitrate removal may also be an objective. One of the key constraints for groundwater desalination is brine disposal. Existing facilities are either located near a brackish or saline water body or near a brine disposal line, such as the Inland Empire Brine Line (also known as the Santa Ana Regional Interceptor – SARI). These regional interceptors enable sustainable disposal of brine wastes. Several additional lines are planned for the southern California area; constructing them will be a key component of the expansion of brackish groundwater desalination.

As groundwater desalination expands in the future, groundwater overdraft issues will be an integral consideration. At this time, the majority of groundwater desalination occurs in basins with some degree of groundwater management or adjudication. This enables groundwater desalination to be strongly linked to other groundwater uses and recharge activities, IRWM, and local supply.

Current Sea Water Desalination

Most of the desalination facilities using sea water as source water currently operating in California are for non-potable uses. Both potable and non-potable sea water existing facilities are shown in Figure 10-5 because these facilities provide context for uses and contribute to understanding overall water supply in California.

Only four facilities (Morro Bay, Avalon, Nicholas Island, and Sand City) are currently used routinely for potable supply. Because of operating expenses, potable sea water desalination facilities often operate intermittently. Morro Bay can operate using either groundwater or sea water as the feed water.

Several communities in California are grappling with whether to invest in sea water desalination for routine or drought water supply. Projects include facilities to be constructed with both public and private funds. The issues being considered vary significantly, but the common issue is the contentiousness of the discussions. In San Diego County at Carlsbad, a 50mgd seawater desalination plant with RO technology is currently under construction.

PLACEHOLDER Figure 10-5 Existing California Brackish and Sea Water Desalination Facilities

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Legal and Regulatory Framework of Desalination in California

General

Water supply projects utilizing desalination technologies are subject to State statutes and regulations as well as local laws. Over [XX] permitting authorities have been indentified for the planning, management, and operation of desalination facilities.

Planning and Management of Water Resources

A general policy framework for desalination in California is set forth in the Cobey-Porter Saline Water Conversion Law (Water Code §§ 12946 – 12949.6). The people of the state have a primary interest in development of economical desalination processes that could:

- Eliminate the necessity for additional facilities to transport water over long distances, or supplement the services provided by long-distance facilities.
- Provide a direct and easily managed water supply to assist in meeting the growing water requirements of the State.

DWR is directed to find economic and efficient methods of desalination so that desalted water (e.g., drinking water or other water) may be made available to help meet the growing water requirements of the State.

Protecting Water Quality

The brackish and sea water environments are important to preserve and protect. Utilizing desalination techniques requires compliance with State and federal laws governing water quality.

The federal Clean Water Act established a permit system known as the National Pollutant Discharge Elimination System (NPDES) to regulate point sources of discharges into navigable waters of the United States.

The Porter-Cologne Water Quality Control Act is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the state's water. This act requires the adoption of water quality control plans by the State Water Resources Control Board and the State's nine Regional Water Quality Control Boards (RWQCBs) for watersheds within their regions. These plans designate beneficial uses for each surface and ground water body of the State, water quality objectives to protect these uses, and implementation measures.

The Porter-Cologne Act also establishes a permitting system for waste discharge requirements for point and nonpoint sources of discharges to both surface water and land. The U.S. Environmental Protection Agency has delegated authority to the RWCQBs to issue NPDES permits. These permits are issued in tandem with waste discharge requirements. These permits are required for disposal of brine from desalination facilities. The permits incorporate provisions in the water quality control plans, including protections of the brackish and sea water aquatic ecosystems.

Protecting Drinking Water

Safe drinking water is dependent upon protection of the surface and ground water sources of water from pollution as well as maintaining appropriate water treatment to remove harmful chemicals and pathogens before they can enter into the drinking water supply. The primary agency responsible for regulating drinking water systems is the California Department of Public Health (CDPH). However, the SWRCB and the RWQCBs also have an important role.

The federal Safe Drinking Water Act (SDWA) directed the U.S. EPA to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of constituents. Local water suppliers are required to monitor their water supplies to assure that regulatory standards are not exceeded. The finished water of a municipal desalination facility must meet these standards. Under the SDWA, the State is required to develop a comprehensive Source Water Assessment Program that will identify the areas that are used to supply public drinking water systems, inventory possible contaminating activities, assess water system susceptibility to contamination, and inform the public of the results. This assessment could include surface and subsurface sources for desalination projects.

The CDPH has primary responsibility for implementing the SDWA in California as well as provisions in State law. In 1999 CDPH issued the "Drinking Water Source Assessment and Protection (DWSAP) Program" (revised in 2000). The program is primarily voluntary on the part of water agencies to perform source water assessments. As of 2003 between 82 and 97 percent of surface and ground water sources were covered by assessments. There is no requirement that these assessments be updated. The implementation measures to protect source waters are a mix of voluntary and mandatory actions by local water and land use planning agencies and the regulatory programs of county health departments, CDPH, SWRCB, and the RWQCBs.

The primary safeguard against pollution of source waters is the RWQCBs through their permitting systems for discharges and other nonpoint source control programs. These permits are based on protecting the beneficial uses of water bodies specified in water quality control plans. By default, bodies of surface and ground water in California are considered suitable or potentially suitable for municipal or domestic water supply and are classified as MUN in water quality control plans (SWRCB, Resolution No. 88-63). One of exceptions is water bodies where the TDS exceeds 3,000 mg/L and it is not reasonably expected by RWQCBs to supply a public water system. However, RWQCBs are to assure that the beneficial uses of municipal or domestic supply are designated for protection wherever those uses are presently being attained. With a few exceptions, RWQCBs have not designated for protection brackish groundwater or ocean water sources currently being treated with desalination for municipal water supply.

Environmental Laws for Protecting Resources

The California Environmental Quality Act (CEQA) is a California statute passed in 1970 to institute a statewide policy of environmental protection. CEQA directly followed the National Environmental Policy Act (NEPA) instituted by the U.S. federal government. CEQA does not directly regulate land uses or other activities. CEQA requires State and local agencies within California to adopt and follow protocols of analysis and public disclosure of environmental impacts of proposed projects and carry out all feasible measures to mitigate those impacts. CEQA makes environmental protection a mandatory part of every California State and local agency's decision making process.

Applying CEQA requirements equally among water supply alternatives (e.g., fresh, brackish, sea, and direct/indirect recycling) is essential for determining the best water supply project to implement.

Protecting Endangered Species and Habitats

There are federal and State laws to protect endangered species of wildlife and their habitats. These laws are encountered with desalination intakes and brine discharges.

Federal Endangered Species Act (ESA). The ESA is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery. Under the federal ESA, an endangered species is one that is in danger of extinction in all or a significant part of its range, and a threatened species is one that is likely to become endangered in the near future. The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS).

Federal agencies, in consultation with the USFWS or NMFS, must ensure that their actions do not jeopardize the continued existence of the species or habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions, including issuance of federal permits, such as the dredge and fill permit required under Section 404 of the federal Clean Water Act, trigger federal ESA requirements that the project proponent demonstrate that there is no feasible alternative consistent with the project goals that would not affect listed species. Mitigation is required if impacts on threatened or endangered species cannot be avoided.

The federal ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. Take has been broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in taking listed species. The permit normally contains conditions to avoid taking listed species and to compensate for habitat adversely impacted by the activities.

California Endangered Species Act (CESA). The California Endangered Species Act is similar to the federal ESA. Listing decisions are made by the California Fish and Game Commission. All State lead agencies are required to consult with the Department of Fish and Game about projects that impact State listed species. DFG is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless there are overriding social or economic conditions that make such alternatives infeasible. For projects causing incidental take, DFG is required to specify reasonable and prudent measures to minimize take. Any take that results from activities that are carried out in compliance with these measures is not prohibited.

Many California species are both federally listed and State listed. CESA directs DFG to coordinate with the USFWS and NMFS in the consultation process so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Regulatory and Permitting Agencies

Most of the primary agencies that exercise regulatory and permitting authority with regard to water supply facility planning, construction, and operation, and that could exercise authority for construction and operation of desalination facilities in California, are listed in Table 10-5 below with their current primary role. There is a current effort within the State agencies to improve the permitting process of projects along the California coast and there is a recognized need by all stakeholders to formally adopt a coordinated permitting process.

PLACEHOLDER Table10-5 Regulatory Agencies for Municipal Desalination Projects

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

[The California Coastal Commission and the State Lands Commission roles will be discussed.]

Regulations for Water Use Efficiency

The State Urban Water Management Planning Act requires urban water suppliers that serve more than 3,000 customers or more than 3,000 acre-feet per year to prepare and adopt urban management water plans. The plans must contain several specified elements, including identifying feasible desalination water supply alternatives. The act also requires water suppliers to review and update their plans at least once every five years.

Potential Benefits

General

Desalination is becoming increasingly important in certain locations and circumstances throughout California. Coastal and inland communities are piloting and implementing full-scale brackish and sea water desalination facilities to meet water demands for:

- Existing and anticipated population growth.
- Replacing imported water deliveries (State Water Project and Colorado River).
- Increasing reliability for periods of local drought.
- Safeguarding against disaster scenarios (risk reduction) which could affect imported or natural fresh water deliveries (e.g., Delta levee failure, out-of-region and statewide droughts, and earthquake damage to conveyance systems).
- Fulfilling restoration and sustainability commitments for the natural environment. Restoration or protection of freshwater habitat may diminish availability of freshwater that is currently being used. Desalination at the place of use may offset freshwater that is necessary for restoration or sustainability commitments.
- Cleaning up and remediating groundwater basins.
- Implementing strategic planning initiatives for climate change adaptation.
- Protecting all water sources (fresh and saline) from degradation.
- Bringing better quality and quantity of water to disadvantaged communities, as a way to practice environmental justice.

The list above is not intended to be exhaustive, but it highlights the multiple potential benefits that may be achieved by building a desalination facility.

1. [Brief discussion on--existing and anticipated population growth]
2. [Brief discussion on--replacing imported water deliveries (State Water Project and Colorado River)]
3. [Brief discussion on--increasing reliability for periods of local drought]
4. [Brief discussion on--safeguarding against disaster scenarios (risk reduction) which could affect imported or natural fresh water deliveries (e.g., Delta levee failure, out-of-region and statewide droughts, and earthquake damage to conveyance systems)]
5. [Brief discussion on --fulfilling restoration and sustainability commitments for the natural environment]

6. [Brief discussion on--implementing strategic planning initiatives for climate change adaptation,
7. [[Brief discussion on--protecting all water sources (fresh and saline) from degradation]
8. [Brief discussion on--practicing environmental justice.]

[The paragraphs below will be merged into these topics]

Desalination provides a means to protect and preserve current drinking water supplies (ground water and surface water) by relieving groundwater over-drafting, stemming seawater intrusion, and maintaining surface flows for the environment. When addressing projected climate change impacts, the inclusion of saline water bodies as drinking water sources is likely essential.

In times of water scarcity, population growth, and climate change, water resources are expected to become more stressed. Traditional water supply management methods such as surface water storage, groundwater extraction, and inter-basin water transfer may not be sufficient to meet increasing water demand. Given that conventional water sources are often limited by overdraft, depletion, pollution, and environmental requirements, desalination can be a reliable water supply alternative and a part of the solution for meeting current and future water needs.

Through desalination, even small scale desalination facilities can serve to meet sustainability and reliability objectives for municipal water supply by providing an emergency water supply. Such facilities as mobile water treatment units including those that can desalt sea or other saline waters can provide emergency potable water supply for towns and communities during droughts, emergencies, or unplanned disruption of their water supplies. These mobile water desalination units are generally reverse osmosis technology that can be truck-mounted or air-lifted and quickly and easily deployed to the water-short areas. Unlike permanent desalination plants, temporary mobile units can be commissioned, installed, and put into production in a short period of time provided environmental and other concerns are addressed. They can also be quickly moved or decommissioned as necessary. [Reference to be added]

[Required coordination of contingency plans involving desalination?]

Potential Costs

General

The cost of desalination depends on numerous factors that are project-specific. When planning desalination projects, it is important that cost estimates take into account the costs of concentrate management and intake systems, including environmental and permitting costs, process costs (i.e., costs of pre-treatment, post-treatment, and main desalting process) and distribution costs.

The cost and affordability of desalination is influenced by the type of source water, the available concentrate disposal options, the proximity to distribution systems, and the availability and cost of power. The higher costs of desalting may, in some cases, be offset by the benefits of increased water supply reliability or the environmental benefits from substituting desalination for a water supply with higher environmental costs. When comparing the cost and impacts of desalination as a water supply option, it is important to compare it to the development of other new treated water supply options.

Technological advances in desalination in the last 20 years have significantly reduced the cost of desalinated water to levels that are comparable, and in some instances competitive, with other alternatives for acquiring new water supplies. Membrane technologies in the form of reverse osmosis (RO) have the most significant improvement. Continuing improvements in system design, membrane technology and energy efficiency and recovery have helped increase efficiency and reduce costs and energy demand. The RO process has been proven to produce high quality drinking water throughout the world for decades.

[Cost data from sources such as the Pacific Institute and WateReuse Association reports will likely be added.]

Major Implementation Issues

General

Following is a list of major factors influencing desalination as a viable resource management strategy:

- Permitting and regulatory framework
- Energy Use and Sources
- Climate Change
- Funding
- Concentrate (Brine) Management
- Planning and Growth
- California's Ocean and Freshwater Ecosystem
- Contamination from urban runoff and microbial content (take-up in ocean intakes)

A brief description of these major factors is provided in the next sections.

Permitting and Regulatory Framework

Two permitting and regulatory issues have been identified: coordination of permitting and protection of source waters used for municipal drinking water. As described in the "Legal and Regulatory Framework of Desalination in California" section above, there are over 35 federal, State, and local agencies that have some regulatory or permitting authority over desalination projects. While any single project may not have to encounter all of these, the regulatory process can be formidable and lengthy. A need for coordination between agencies has been indentified (DWR 2003, Water Desalination: Findings and Recommendations, Sacramento, California, October 2003).

One effort to improve coordination is the creation of the State agency Desalination Interagency Workgroup in 2012. It has been proposed that the State permitting agencies establish an agency priority sequence for permit reviews to improve coordination at the project level.

A key element in the protection of sources of drinking water is the designation of water bodies for this beneficial use in water quality control plans adopted by the RWQCBs and SWRCB. As described in the "Legal and Regulatory Framework of Desalination in California" section, brackish and seawater sources being used for municipal drinking water after desalination are not designated for this beneficial use. Desalination is very effective in removing constituents in water that could be harmful to human health; however, desalination does not remove all chemicals, including some chemicals with known health effects. There is a general concern in water quality management about the thousands of manufactured chemicals introduced into the environment with little or no testing for human or environmental effects. These chemicals are commonly referred to as chemicals of emerging concern (CEC). A regulatory strategy has not been developed to prevent potentially harmful CECs or other chemicals of known health effects from occurring in brackish or seawater sources of drinking water. Source water assessments can be used to identify zones of protection for saline waters used for drinking water, assess the potential contaminant activities, and identify chemicals that cannot be normally expected to be removed by desalination. Water quality control plans can designate zones in saline waters for protection as sources of drinking water after desalination and include appropriate regulatory measures, such as water quality objectives or implementation programs, to provide reasonable protection for this use.

Energy Use and Sources

Energy use is a significant factor in water desalination projects for reasons of costs and environmental impacts of energy generation. Each of the elements in a desalination system, as shown in Figure 10-2, entails energy use, but the most significant energy use is in the desalination treatment process. Generally, the energy requirement of RO desalination is a direct function of the salinity and temperature of the feedwater source. Given similar operating conditions and treatment plant parameters, brackish water desalination is usually less energy intensive, and hence less costly, than seawater desalination. Several summary reports on desalination and energy intensity of water supply and treatment systems have been published that report data on the energy intensity of desalination processes. Drawing from an array of studies (CEC, 2005; CPUC, 2010; Wilkinson, 2007; Pacific Institute, 2012; WeSim, 2012; and Water ReUse Foundation, 2011) energy intensity for sea water desalination ranges between 2,970 kWh/AF to 5,920 kWh/AF and between 978 kWh/AF and 2,704 kWh/AF for brackish water desalination.

In order to compare the energy intensity of desalinated water supplies with the energy intensity of other water supplies provided in each regional report, a factor for water treatment would have to be added to the energy intensities of “raw water” provided in the regional reports. The energy of conventional water treatment is typically between 50 kWh/AF and 2000 kWh/AF depending on the capacity of the treatment plant and the quality of incoming raw water (WeSim, 2012; Water ReUse Foundation, 2011).

For a seawater desalination RO facility, 28 percent to 50 percent of total annual costs, including annual capital recovery costs, are devoted to energy consumption (Water ReUse Foundation, 2011). However, improvements in RO membranes and the incorporation of energy recovery devices in treatment facilities have resulted in reduced energy needs for new facilities compared to older projects. While research continues, it is not expected that further major reductions will occur in the near term. Because of the high energy requirements for desalination it is especially important to look at the sources of power used to operate plants. Although there has been an overall emphasis on expanding reliance on sustainable/renewable energy sources within California, fossil fuel-based power plants continue to be a major source of energy, about 62% of total in-state electricity generation. Significant improvements in energy generation technology have reduced the environmental impacts associated with energy generation, nonetheless, energy generation (including exploration, extraction, and conversion to electricity) continues to result in significant environmental impacts. Air pollution including greenhouse gases, groundwater pollution, water use, and despoiling of scenic views and wildlife habitat are major concerns associated with new and existing energy generation. Many of these concerns do not only apply to just fossil energy sources, but also to renewable power.

Aside from drawing electricity from a power grid to operate desalination, there are proposed concepts to incorporate renewable energy generation directly into a desalination facility. In some proposals, seawater desalination can take advantage of its proximity to natural energy within the ocean environment. A desalination plant that would be driven by wave energy is planned in Australia with government funding (add reference). In addition, research is being conducted on two concepts funded by the U.S. Environmental Protection Agency: the microbial desalination fuel cell and desalination with a solar evaporation array [Add references].

Climate Change

General

As water resource planners and managers move to develop water supplies, they will need to address potential climate change impacts. Climate change projections include warmer air temperatures, diminishing snowpack, precipitation uncertainty, increased evaporation, prolonged droughts, and sea level rise. These anticipated changes could further reduce water supply in many regions including those that are already experiencing difficulty meeting current water demands. Climate change impacts will put additional stress on aging freshwater collection, storage, and conveyance infrastructure reducing the capacity to provide a stable source of drinking water.

Loss of snowpack, prolonged droughts, and sea level rise will likely be some of the most critical impacts for California water managers who may consider desalination in their regional water management portfolios. DWR projects that the Sierra snowpack will experience a 25 to 40 percent reduction from its historic average by 2050, limiting the amount of water that can be supplied during the summer and fall months. Prolonged droughts, with changes in precipitation and runoff patterns will likely impact communities that rely upon surface water deliveries making them more dependent on groundwater sources. Sea level rise could increase salt water intrusion to coastal freshwater aquifers resulting in brackish waters that would require treatment to attain drinking water standards. Whether an overall increase or decrease in precipitation, runoff, or capture occurs due to climate change, initial estimates of watershed models are that increases in temperature and consequent increases in evapotranspiration will cause a higher water demand.

Adaptation

In some regions that are already experiencing difficulty meeting current water demands, a portion of the water supply is already being supplied by the desalting process. As the impacts of climate change continue to intensify, desalination may become a more attractive adaptive strategy. Desalination provides a water supply that remains robust even during extreme drought periods; desalination capacity will not be affected by rising sea levels, decreased exports from the Sacramento-San Joaquin Delta, or changes in snowpack runoff. Therefore, desalination is an adaptation strategy to improve the resiliency and reliability of a region’s water supply even in the face of uncertain future climate conditions.

Mitigation

Because of the higher energy intensity of desalination (when compared to most alternative water supplies) energy use and associated greenhouse gas emissions from desalination pose a major concern. While desalination may be used to increase water supplies and provide a climate resilient and robust water supply, operation of desalination facilities may have associated substantial GHG emissions depending on the type of energy used to operate them; some energy sources contribute to existing atmospheric GHG concentrations and lead to larger future climate changes. Potential mitigation opportunities include reduced energy consumption by increasing operational and process efficiencies and coupling or dedicating renewable/sustainable energy sources not generating GHGs to desalination facilities.

The energy factors provided above in the Energy Use and Sources section can be converted to GHG emissions by using a GHG emission factor for the region or the energy utility that would provide power to for desalination. The California region (CAMX) average GHG emissions rate for electricity is 0.300 metric tons CO_2e/MWh. Emissions rates for specific utilities service areas and other states can be found at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

While desalination is a proven technology, in most cases, its energy requirements are higher than levels necessary for importing and treating water to the region or using local groundwater and surface water sources. Brackish water desalination is comparable in energy intensity with recycled and imported water supplies, while sea water desalination is considerably more energy intensive than most other water supply options. As an energy intensive process, desalination has the potential to counteract the GHG reduction goals of California if fossil fuel powered plants are used as a primary energy source. However, desalination operations can take measures to optimize efficiency, purchase renewable energy, minimize GHGs on-site, and mitigate for emissions off-site to reduce their overall carbon footprint.

California's Ocean and Freshwater Ecosystem

A primary concern associated with coastal desalination plants is the impact of feed water intake on aquatic life. Surface intakes of seawater result in impingement and entrainment of marine organisms. This impact can be avoided by adopting subterranean intakes (e.g., beach wells and under ocean bed intakes) wherever feasible. Proper design of open water intakes can significantly reduce impacts. It is important to have a strong regulatory structure to ensure protection of the ocean and other aquatic environments.

Restrictions put in place to protect fish and wildlife within the inland watershed zone may prevent a community from meeting its freshwater supply from either ground or surface water within the affected watershed zone. Seawater desalination may be the most sustainable option to meet water demands while protecting fresh and brackish water environments.

In the past, seawater desalination has been able to gain cost efficiency by sharing intake and discharge structures with coastal power plants. This option, however, may be diminishing. To reduce the harmful effects associated with cooling water intake structures on marine and estuarine life, the State water Resources Control Board has adopted a policy preventing any new once-through cooling power plants [citation for Once-Through Cooling Policy].

Funding

General (Past, Present, Future)

From the world, national, and State, and local perspective, funding sources have fluctuated since the 1950's. Desalination technology is being used in over 140 countries with investments in desalination research and development likely out pacing the USA (NAP, 2008).

U.S. national desalination research and development efforts are funded through at least nine federal agencies and laboratories, each with their own research objectives and priorities. The majority of federal desalination research and development funding also comes from congressional earmarks, which limit the ability to develop a steady research program (NAP, 2008, Page 30).

Financial aid and other funding opportunities are critical to the progression of Desal-RMS at the national, State, regional, and local levels. The recent successful progression of desalination from a cost prohibitive alternative to the alternative of choice is attributed, in part, to funding.

The funding mechanisms available for the progression of desalination in California are grants, loans, and rebates. The California legislature emphasized the importance of water desalination in 2003 with the passages of Assembly Bill 314, which declared that it is the policy of the State that desalination projects developed by or for public water entities be given the same opportunities for State assistance and funding as other water supply and reliability projects.

Grants (Past, Present, Future)

In November 2002, California voters passed Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002. Chapter 6 of that proposition authorized $50 million in grants for brackish water and ocean water related funding. The grant program aimed to assist local public agencies with the development of new local potable water supplies through the construction of feasible brackish water and ocean water desalination projects and advancement of water desalination technology and its use by means of feasibility studies, research and development, and pilot and demonstration projects. Two cycles of funding under this grant program were conducted during 2005 and 2006, competitively awarded approximately $46.25 million in grants to 48 projects including 7 construction projects, 14 research and development projects, 15 pilots and demonstrations, and 12 feasibility studies.

This program has resulted in approximately 30 thousand acre-feet of water produced annually from the five completed construction projects. A third round of funding is underway and slotted for the 2013-2014 fiscal year with approximately $8.7 million of unused grant funds.

Another source of funding for desalination is the for integrated regional water management (IRWM) Grant Program. In 2002, Senate Bill 1672 created the Integrated Regional Water Management Act to encourage local agencies to work cooperatively to manage local and imported water supplies to improve the quality, quantity, and reliability. This water management style engages diverse stakeholders with a multitude of perspectives to arrive at multibenefit projects (including desalination projects) to meet several goals and objectives in a more cost effective manner than each entity acting on its own. Two propositions contained bonds to fund IRWM projects: Proposition 50 in 2002 and Proposition 84 in 2006. This program has resulted in over 10 desalination projects. IRWM implementation grants are planned for the 2014-2015 fiscal year pending the legislative appropriation of bond funds. Final program guidelines and proposal solicitation are projected to be released in the fall of 2014 with the applications due winter 2014/2015.

Loans (Past, Present, Future)

[General information concerning grant loans for desalination will be provided in this section.]

Rebates (Past, Present, Future)

[General information concerning rebates for desalination projects will be provided followed. As an example, there are rebate programs offered by the Metropolitan Water Districts (MWD) for desalination.]

Other (Past, Present, Future)

[General information concerning “other” as required rebates for desalination projects in this section. This subheading may not be needed. Readers should provide information to DWR if they are aware of funding not fitting into the previous subsections for inclusion here.]

Concentrate (Brine) Management

The desalination process produces a salty concentrate (brine) that must be properly managed. This brine must be handled in an environmentally safe and sustainable manner in accordance with regulations. The quantity and salinity of the concentrate varies with the type of technologies employed in operating the plant.

Brine management alternatives for disposal include but are not limited to processes utilizing:

- Discharge to separate permitted wastewater collection and treatment systems.
- Discharge and dispersion to water bodies such as oceans and bays.
- Discharge by land application usually involving further solids disposal after evaporation of liquid portion of discharge.
- Discharge to deep groundwater wells through an injection process.
- Disposal processes using further treatment trains resulting in what is termed “zero liquid discharge” disposal whereby the solids produced have reuse potential and thus are not sent to waste and nearly all water is recovered.

It is more likely that brackish water plants in California discharge their concentrate to municipal wastewater treatment systems where it is incorporated, treated, and disposed of with other municipal wastewater. For brackish water desalination plants, this type of concentrate management is likely to continue where the wastewater treatment system capacity is adequate. Plant locations where suitable wastewater collection and treatment systems are not available or locations without a discharge to the ocean may be limited by the type of discharge options available. Seawater desalination produces a concentrate approximately twice as salty as seawater. In addition, residuals of other treatment chemicals may also be in the concentrate of brackish and seawater. Some plants currently being planned will use existing power plant or wastewater plant outfall systems to take advantage of dilution and mixing prior to discharge to the ocean or adjacent water bodies. The availability of power plant cooling systems to dilute the concentrate prior to discharge to the ocean will also be affected by the future of coastal power plants as discussed in the California's Ocean and Freshwater Ecosystem Section. On the other hand, co-locating concentrate discharge with wastewater effluent outfall might have some environmental benefits to the extent that the concentrate from the desalination plant would increase the salinity of the wastewater effluent to levels that are comparable or closer to that of seawater.

Brine discharges from desalination facilities are regulated by the State Water Resources Control Board through the issuance of a National Pollutant Discharge Elimination System (NPDES) permit that contains conditions protective of aquatic life. Concentrate management requires integration with other plans adopted by the State such as the Ocean Plan and Enclosed Bays, Estuaries and Inland Surface Waters Plan. The Ocean Plan does not currently have an objective for elevated salinity levels in the ocean, nor does it describe how brine discharges are to be regulated and controlled, leading to permitting uncertainty. The Ocean Plan also does not address possible impacts to marine life from intakes for desalination facilities. An Ocean Plan amendment is currently underway as this chapter was drafted and is envisioned to have the following components: a "narrative" objective for salinity, provisions to minimize impacts to marine life from desalination plant intakes, and implementation provisions. State Water Board staff anticipates that the Ocean Plan amendment will be completed by late 2013.

Planning and Growth

There are many factors to consider before deciding whether to implement a water desalination project. Desalination should be analyzed in comparison with other alternatives that could achieve the same project objectives. In the context of this resource management strategy, obtaining a municipal water supply would be a primary objective. There are established feasibility criteria that are applied in water resources planning:

- Ability to meet project objectives.
- Technical feasibility.
- Economic justification.
- Financial feasibility.
- Environmental feasibility.
- Institutional feasibility.
- Social impacts.

As with any water resources project, desalination cannot be evaluated on the basis of any single criterion. Water supply alternatives rarely include an outstanding alternative that meets all of a community's vision for the future and the needs and goals to achieve that vision. All alternatives, including desalination, needed to be evaluated together applying the evaluation criteria listed above.

Drawing on the work of the California Water Desalination Task Force, which was convened in 2003, DWR published the *California Desalination Planning Handbook* (DWR, 2008). This handbook is a valuable resource for project proponents and communities. It provides a planning framework for developing, where appropriate, economically and environmentally acceptable desalination facilities in California. The planning process outlined in the handbook is intended to identify and address citing, regulatory, technical, environmental and other issues, which should be considered in determining whether and how to proceed with a desalination project.

There are major issues facing desalination, as described in other sections, including cost, environmental impacts, greenhouse gas emissions, and growth inducement. A methodical planning process with community involvement is the best procedure to minimize negative impacts and to weigh these impacts against those of other water supply options and the supply reliability and other benefits of desalination. Even the presence of unavoidable adverse impacts may be acceptable. As stated in the regulations implementing CEQA:

> "CEQA requires the decision-making agency to balance, as applicable, the economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposed project against its unavoidable environmental risks when determining whether to approve the project. If the specific economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposal project outweigh the unavoidable adverse environmental effects, the adverse environmental effects may be considered "acceptable."" (California Code of Regulations, Title 14, Division 6, Chapter 3, section 15093(a))

One of the issues has been the assertion that desalination is "growth-inducing." Any water supply or water management alternative, including water conservation that augments or frees up water supply to accommodate new water demands has the same potentially growth-inducing impact. A community's vision for population growth and land development ideally should be resolved in a broader context of community planning, such as county general plans, not water supply planning. CEQA guidelines require that growth-inducing impacts of a proposed project be discussed in environmental documents. However, as stated in the guidelines, "It must not be assumed that growth in any area is necessarily beneficial, detrimental, or of little significance to the environment." (California Code of Regulations, Title 14, section 15126.2(d))

The goal of a the water resources planner is to meet the needs of the community for a reliable water supply now and in the future as the public has envisioned future land use and population. Desalination is part of the portfolio of potential supplies that should be considered. An analysis of desalination is required as part of urban water management plans complying with the Urban Water Management Planning Act (Water Code section 10631) and integrated regional water management plans submitted as part of the Integrated Regional Water Management Grant Program.

Recommendations

General

Desalination of sea and brackish water is a proven technique to augment water supplies in a balanced water supply portfolio. Treatment of brackish groundwater for beneficial use is a common practice in California and in some instances may approach conventional treatment status. Small scale seawater desalination facilities, less than 5 million gallons per day, have been built but as of 2013, desalination facilities have not become an established method to meet municipal water demands.

Desalination, particularly of sea water, has been a challenge. If desalination is to be an appropriate and successfully implemented component of California's water supply, certain constraints need to be agreed upon and certain actions need to take place in the planning, regulatory, and scientific arenas.

Nevertheless, sea and brackish surface waters are potential water supplies in many parts of California as they are throughout the world, and water supply planners in California are continuing to include desalination of saline water to diversify water supply portfolios.

The following general recommendations are maintained for proper implementation of Desal-RMS.

Policy

1. The State recognizes that desalination is an important water supply alternative and, where economically, socially and environmentally appropriate, should be part of a balanced water supply portfolio, which includes other alternatives such as conservation and water recycling.
2. Only environmentally sound desalination should be implemented. Regulatory agencies should have a strong regulatory framework with adequate resources to establish technically sound criteria that provide adequate environmental safeguards for water supply projects including desalination.
3. The State recognizes that desalination requires energy to operate and to mitigate the energy needs where economically and environmentally appropriate, project sponsors and water suppliers should consider coupling energy from sustainable sources.

[DWR is considering a policy or specific action level recommendation for establishing a State funding source for desalination implementation and research projects.]

Actions

4. Project sponsors and water suppliers should evaluate desalination techniques, both groundwater and surface waters, alongside and combined with municipal wastewater recycling, including the indirect and direct potable reuse, as a means to meet existing and future water demands. This evaluation will provide a means for communities across the state to make sound choices on water supply options as appropriate through science based decision making for a sustainable future.
5. When planning a water supply project as part of an integrated regional water management plan prepared for State funding, project sponsors and water suppliers shall consider desalination as a strategy to meet the goals and objectives of the region [California Water Code §10530].
6. Desalination should be evaluated using the same well-established planning criteria applied to all water management options, using feasibility criteria such as: water supply need within the context of community and regional planning, technical feasibility, economic feasibility, financial feasibility, environmental feasibility, institutional feasibility, social impacts, and climate change. The California Desalination Planning Handbook published by DWR should be one of the resources used by water supply planners.
7. Project sponsors and water suppliers should evaluate desalination within the context of integrated water management reflecting community and regional needs and priorities with respect to water quality protection, water supply, growth management, brine disposal and economic development. Water management planning has to occur within a wider context of community values and visions for the future. Key stakeholders, the general public, and permitting agencies need to be engaged in the planning process.
8. DWR, in collaboration with regulatory agencies, should lead an effort to create a coordinated streamlined permitting process for desalination projects. Because of the many regulatory agencies involved in desalination of ocean, bay or estuarine waters, a coordinated framework to streamline permitting approvals without weakening environmental and other protections should be explored. Establishing an appropriate sequencing of approval by the various agencies may be

appropriate. The Ocean Protection Council may be appropriate for the role of coordinating regulatory reviews and guiding project sponsors through the regulatory process.

9. Project sponsors and water suppliers should evaluate climate change impacts, primarily due to greenhouse gas generation from energy consumption, for proposed desalination projects within the context of available water supplies alternatives. Note that desalination should not be precluded solely on the basis of energy consumption, because the allocation of energy to meet water supply needs and reliability may be considered of higher social value to a community than other uses of energy.
10. Desalination projects developed by public agencies or utilities regulated by the California Public Utilities Commission should have opportunities for State assistance and funding for water supply and reliability projects.
11. Research and investigations should continue to develop new or improved technologies to advance and refine desalination processes, feedwater intake and concentrate management technologies, energy efficiencies, and the use of alternative and renewable energy sources.
12. DWR should be adequately funded to maintain technical expertise and current data on the status of brackish and seawater desalination in California to support the planning and policy roles of State government and to be an information resource to the public.
13. The SWRCB, in consultation with CDPH and DWR, should develop an effective regulatory framework for protection of saline waters for the beneficial use of municipal drinking water after desalination treatment through Source Water Assessment Plans and Water Quality Control Plans. The framework should provide reasonable protection against CECs or constituents known to be harmful in drinking water which can not reliably, readily, and feasibly be removed with existing technology such as currently employed in RO desalination systems.

Desalination in the CWP

Desalination in the RMS

The following resource management strategies included in this volume have been identified and closely linked to the Desal-RMS and should be investigated accordingly to understand their relationship to meeting regional and local water supply objectives:

- Chapter 11, “Recycled Municipal Water.”
- Chapter 24, “Land Use Planning and Management.” [this section to be expanded to include the RMS connectedness as needed]
- Chapter 15, “Drinking Water Treatment and Distribution.”
- Salts are naturally occurring in the environment, but human activity often increases salinity in water and soil. Because of the negative impacts of salinity on human use or the water environment (fresh and saline), salinity management is a critical resource management strategy (see Chapter 19,” Salt and Salinity Management”).

References

[Under development, not complete at this time]

References Cited

[References cited (RC) in the CWP Update 2009 have been placed under the “References Cited” subheading below with [2009 RC] preceding the reference. Upon final 2013 draft completion, the

"Additional References" subheading will be used to list any [2009 RC] not specifically requiring citing and relevant references will be given.]

[2009 RC = Reference Cite in 2009 Update; this section is under development and is not complete at this time.]

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Additional References

[This section is under development and is not complete. This section will included previous references from past Updates and other pertinent references.]

Personal Communications

[This section is under development and is not complete.]

Table 10-1 Measurements of Salinity

Salinity metric	Common Units	Comment
Electrical conductivity (EC)	μS/cm	EC is a measure of the concentration of dissolved ions in water, and is reported in μmhos/cm (micromhos per centimeter) or μS/cm (microsiemens per centimeter). A μmho is equivalent to a μS. EC may also be called specific conductance or specific conductivity of a solution.
Total dissolved solids (TDS)	mg/l or ppm	TDS is a measure of the all the dissolved substances in water and its units are milligrams per liter (mg/l) of solution.
Practical salinity units (PSU)	Unit-less	PSU is approximately equivalent to salinity expressed as parts per thousand (e.g., salt per 1,000 g of solution). Seawater is about 35 PSU. Its actual measurement is a complex procedure. Oceanographers are likely to use PSUs, which is why it is mentioned here.

Table 10-2 Gradation Common Terms

General Water Term	Relative Salinity, mg/L (ppm) TDS
Fresh raw (natural)	Less than 1,000 [a]
Brackish	1,000 to 30,000
Sea	30,000 to 50,000
Hypersaline	Greater than 50,000 or that is found in the sea
Natural brine	Greater than 50,000 to slurries [b]
Discharge brine	1,000 to slurries [c]

[a] Based on community drinking water standards. Salinity target values for municipal drinking water systems using desalination technologies are typically less than 500 ppm TDS.

[b] Also, brines or “salines” naturally derived from groundwater are 100,000 ppm or greater. TDS, NaCl-saturated solutions are approx. 260,000 ppm in concentration.

[c] Discharge brine concentrations vary widely and are dependent upon technologies employed and processes used to discharge brine as a final waste stream to the environment. The concentration of reject water from a desalination facility may be referred to as “brine” but may only be 4,000 mg/l TDS in concentration.

Table 10-3 General Desalination Technology List

	Thermal Distillation
Technology	**Brief Description**
Multi-Stage Flash evaporation (MSF)	The thermal process by which distillation principles are employed through chambers at slightly different atmospheric pressures to flash liquid water into vapor and immediately condense in adjacent chambers as product water for use. [Reference for additional information needed here]. Large-scale sea water desalination facilities used in many other parts of the world with oil used for energy at less than market prices. Not currently used or proposed in California.
Multi Effect Distillation (MED)	The thermal process by which distillation principles are employed through pipes rather than chambers as in MSF. Once evaporation has occurred, water vapor is condensed within tubes (pipes) rather than chambers. [Reference for additional information needed here]. MED may be more efficient than MSF.
Vapor Compression (VC)	
	Membrane Separation
Technology	**Brief Description**
Electrodialysis (ED)	
Nanofiltration (NF)	
Reverse Osmosis (RO)	Reverse osmosis (RO) is similar to other membrane processes, such as ultrafiltration and nanofiltration, in that water passes through a semi-permeable membrane. However, in the case of RO, the membrane is non-porous. RO involves the use of applied hydraulic pressure to oppose the osmotic pressure across the membrane, forcing the water from the concentrated-solution side to the dilute-solution side. The water dissolves into the membrane, diffuses across, then dissolves out into the permeate.
Forward Osmosis (FO)	Forward osmosis is an intriguing approach that utilizes the conventional osmosis principle. It was considered years ago, but has recently been targeted for development because of improved membrane materials and new techniques including advanced energy recovery equipment.
Microfiltration membranes (MFM)	
Ultrafiltration Membranes (UFM)	
Capacitive Deionization Technology ™	Pilot stage, experimental — an alternative to RO and other desalination technologies.
Ion Exchange	Ion exchange involves the selective removal of charged inorganic species from water using an ion-specific resin. The surface of the ion exchange resin contains charged functional groups that hold ionic species by electrostatic attraction. As water passes by the resin, charged ions on the resin surface are exchanged for the contaminant species in the water. When all of the resin's available exchange sites have been replaced with ions from the feed water, the resin is exhausted and must be regenerated or replaced [EPA-- Drinking Water Health Advisor For Boron]
	Other Technologies

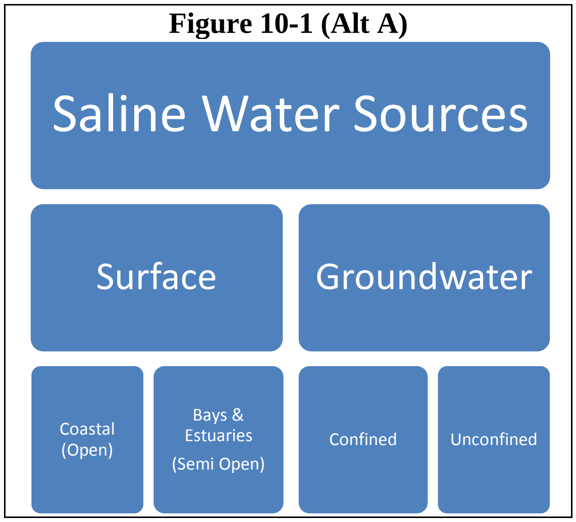
Table 10-4 Brief Description of Membranes

[table to come]

Table 10-5 Regulatory Agencies for Municipal Desalination Projects

Agency or Department	Permit or Approval	Required for
Federal Agencies		
National Marine Sanctuaries	Research Permit or Authorization; Education Permit; Authorization Permit	Review of other State and federal permits (including U.S. Army Corps of Engineers permits, Regional Water Quality Control Board 401, and NPDES permits) with activities/discharges into waters and wetlands.
U.S. Fish and Wildlife Service (USFWS)	Endangered Species Act compliance (ESA Section 7 consultation)	Incidental take of federally listed species.
	Fish and Wildlife Coordination Act (16 U.S.C. 661-667e; the Act of March 10, 1934; ch. 55; 48 stat. 401)	Provide comments to prevent loss of and damage to wildlife resources.
National Oceanic & Atmospheric Administration (NOAA) – Fisheries	Endangered Species Act compliance (ESA Section 7 consultation)	Incidental take of federally listed species.
Army Corps of Engineers (Corps)	Nationwide Permit No. 6, Survey Activities	Survey activities, such as core sampling, seismic exploratory operations, soil surveys, sampling, and historic resources surveys.
	Nationwide Section 404 Permit (CWA, 33 USC 1341)	Discharge of dredge/fill into Waters of the United States, including wetlands.
	Nationwide Permit No. 7, Outfall Structures and Associated Intake Structures	Activities related to the construction or modification of outfall structures and associated intake structures where the effluent is authorized by NPDES, Section 402 of the Clean Water Act.
	Section 10, Rivers and Harbors Act Permit (33 U.S.C. 403)	Activities, including the placement of structures, affecting navigable waters.
U.S. Coast Guard	Federal Consultation	Coastal Commission Coastal Development Permit and ACOE Section 10 Permit.
State Agencies		
State Water Resources Control Board, Regional Water Quality Control Board	General Construction Activity Storm Water Permits.	Storm water discharges associated with construction activity.
	401 Water Quality Certification (CWA Section 401)	Discharge into waters and wetlands (see USACE Section 404 Permit).
	National Pollutant Discharge Elimination System (NPDES) Permit (CWA Section 402)	Discharge into waters and wetlands.
California State Lands Commission	Right-of-Way Permit (Land Use Lease) (California Public Resource Code Section 1900)	Issuance of a grant of right-of-way across state lands.
	Lease Amendment	Modification of Wastewater Outfall lease.
California Department of Fish and Wildlife (CDFW)	Incidental Take Permits (CESA Title 14, Section 783.2)	Activity where a State-listed candidate, threatened, or endangered species under California ESA may be present in the project area and a State agency is acting as lead agency for CEQA compliance.
California Coastal Commission (CCC)	Coastal Development Permit. (Public Resources Code 30000 et seq.)	Development within the Coastal Zone, excluding areas where local jurisdictions have approved Local Coastal Plans in place.
California Department of Public Health (CDPH)	Permit to Operate a Public Water System (California Health and Safety Code Section 116525)	Operation of a public water system. (Amendment only.)
California State Historic Preservation Officer (SHPO)	Section 106 Consultation, National Historic Preservation Act (16 USC 470)	Consult with project applicant, appropriate land management agencies, and others regarding activities potentially affecting cultural resources.

Figure 10-1 Basic Municipal Drinking Water Facility and Source Waters in California



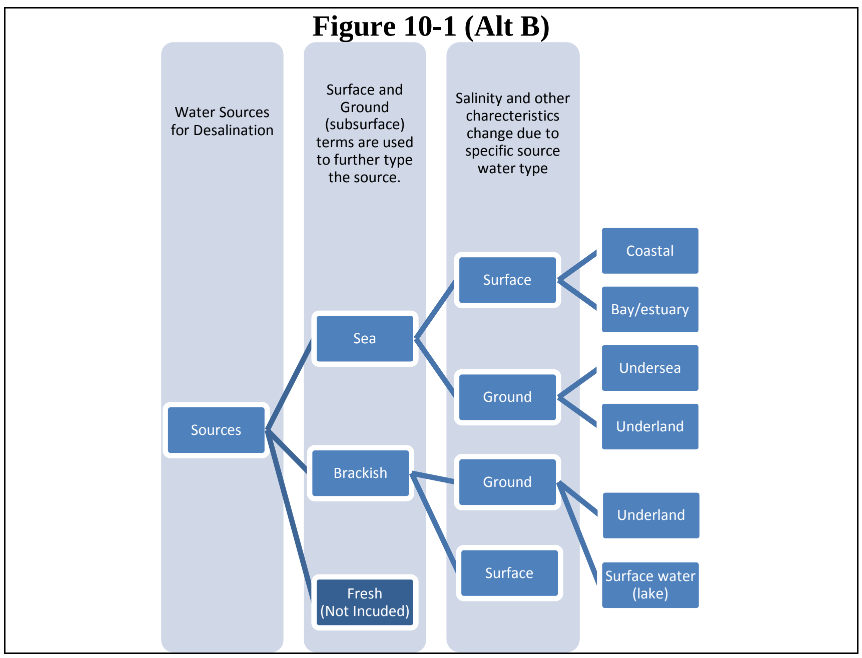
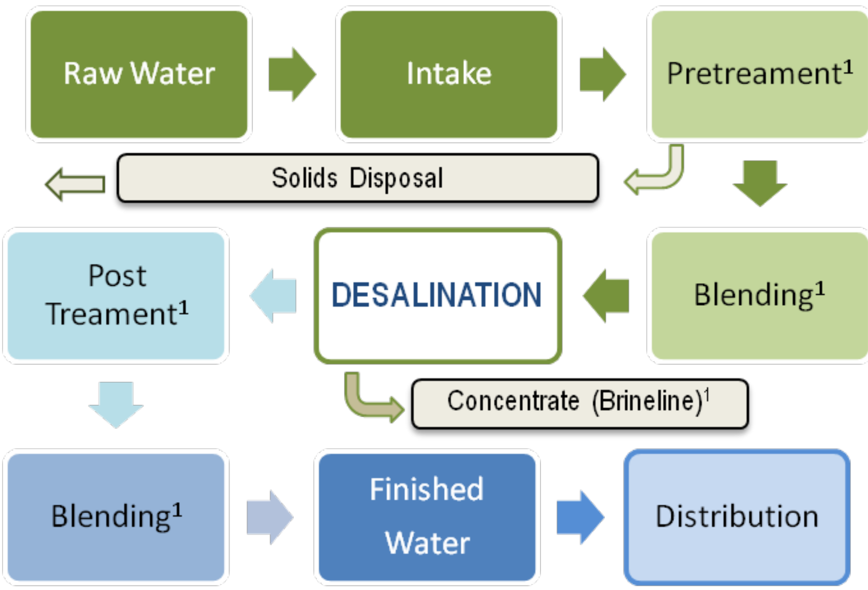


Figure 10-2 General Distinctions for Location

[figure to come]

Figure 10-3 General Desalination System Schematic



1. May not occur at specific desalination facilities.

Figure 10-4 The Filtration Spectrum

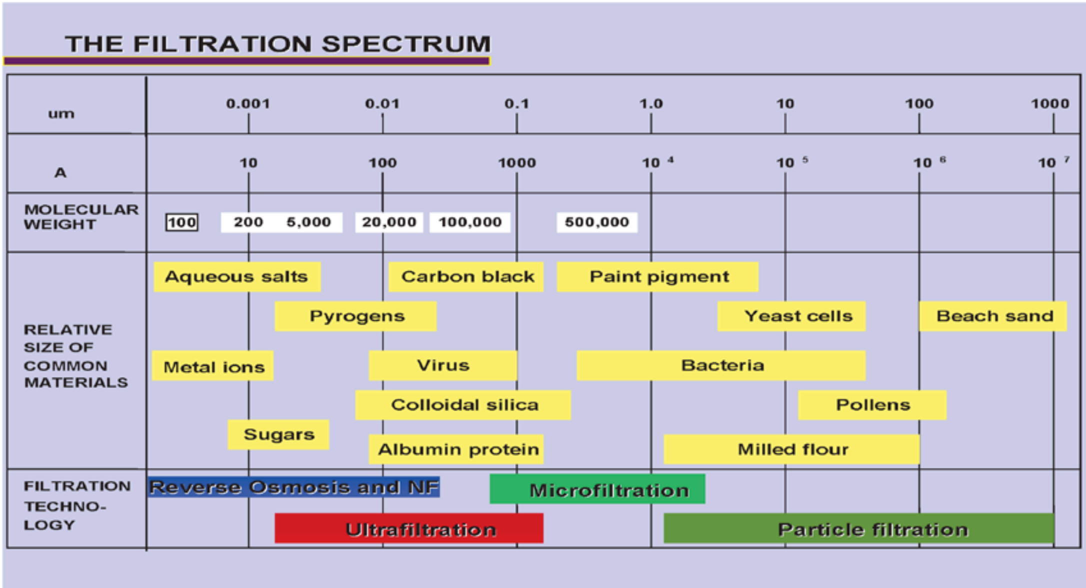


Figure 10-5 Existing California Brackish and Sea Water Desalination Facilities

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Chapter 12.Municipal Recycled Water

California is increasing its integration of municipal recycled water into its water supply portfolio. In some parts of the state, recycled water meets approximately 7 percent of water supply demands. Although the statewide total is an increase since *California Water Plan Update 2009* (Update 2009) was released, it is still far short of previously established goals. Municipal recycled water benefits the state and individual water users by reducing water conveyance needs, providing local water supplies, and being a drought-resistant resource. This resource management strategy (RMS) chapter will describe the current status of recycled water in California, what some of the challenges are to its increasing use, and the resources needed to continue to increase municipal recycled water use.

Introduction

The municipal recycled water RMS addresses the recycling of municipal wastewater treated to a specified quality to enable it to be used again. Within this chapter, the term "recycled water" refers to water that originates from a municipal treatment plant. Treated wastewater is primarily from domestic (household) sources, but it can include commercial, industrial, and institutional (CII) wastewater discharged to a sanitary sewer. This RMS does not address other types of water recycling, such as the reuse of:

- Industrial wastewater, either when internally reused or when treated or disposed separately from municipal wastewater.
- Agricultural wastewater.
- Gray water.

These are addressed in other parts of *California Water Plan Update 2013* (Update 2013).

Changes in this Strategy Since 2009

The Update 2013 municipal recycled water RMS is extensively changed from the version that appeared in Update 2009. There are new or revised policies (the 2009 Recycled Water Policy adopted by the State Water Resources Control Board [SWRCB]), proposed regulations (the California Department of Public Health's [CDPH's] 2011 draft regulations for groundwater replenishment with recycled water, as part of Senate Bill [SB] 918), and a new statewide survey of recycled water users. In addition, several reports that describe recycled water applications, benefits, and challenges have been prepared. Each of these will be discussed within this chapter.

Affiliations with other Resource Management Strategies

Treating and delivering recycled water, as well as disposing of byproducts that may result from generating recycled water, involve issues that may also be discussed in other RMS chapters within Update 2013. The key affiliations of other RMSs to recycled water, shown in Figure 12-1, are described below, by chapter.

- **Chapter 2, "Agricultural Water Use Efficiency"** — Recycled water can be used to irrigate most crops.

- **Chapter 3, "Urban Water Use Efficiency"** — Recycled water can be used for landscape irrigation and commercial or industrial applications. This chapter describes gray water applications.
- **Chapter 6, "Conveyance — Regional/Local"** — Distribution of recycled water is planned and implemented on local and regional levels with local conveyance systems.
- **Chapter 15, "Drinking Water Treatment and Distribution"** — In the future, recycled water may be distributed via potable water distribution systems.
- **Chapter 17, "Matching Water Quality to Use"** — Recycled water could replace many instances where potable water is currently being used for non-potable applications.
- **Chapter 19, "Salt and Salinity Management"** — Recycled water production may result in brine generation. Use of recycled water may also have an overall impact on salinity of the underlying groundwater basin. Discharges of salts and chemicals into sewers from water softeners can increase wastewater salinity and negatively affect municipal recycling.
- **Chapter 20, "Urban Stormwater Runoff Management"** — Stormwater can be used as a water supply mixing source for projects where recycled water is used for groundwater recharge.
- **Chapter 22, "Ecosystem Restoration"** — Recycled water is often a water supply for ecosystem restoration projects.
- **Chapter 24, "Land Use Planning and Management"** — Use of recycled water can be constrained by the availability of sites suitable for recycled water. Successful local planning can encourage locating potential recycled water users where recycled water is available, as well as planning infrastructure needs to support future growth.
- **Chapter 28, "Economic Incentives — Loans, Grants, and Water Pricing"** — Economic incentives are commonly used to initiate recycled water projects, enable infrastructure development, or support the use of lower quality water.
- **Chapter 29, "Outreach and Education"** — Introduction of recycled water as a local water supply resource requires extensive public outreach and education regarding its uses, as well as addressing local water quality and health effect concerns.

PLACEHOLDER Figure 12-1 Municipal Recycled Water Affiliations with Other Resource Management Strategies

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Definition of Municipal Recycled Water

The California Water Code (CWC) provides the following definition for recycled water: "water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefor [sic] considered a valuable resource" (CWC Section 13050(n)). "Recycled water" and "reclaimed water" have the same meaning and can be used interchangeably. The California Water Plan uses the term "recycled water." An illustration of the many paths that municipal recycled water can take for reuse is shown in Figure 12-2. The recycled water pathways shown in this figure do not indicate the level of recycled water treatment. Existing California law specifies required treatment levels for designated uses.

PLACEHOLDER Figure 12-2 Municipal Recycled Water Cycle

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

[This figure will be updated. Current figure is a mock-up.]

Municipal water recycling is a strategy that increases the usefulness of water by reusing a portion of the existing waste stream that would be discharged to the environment as waste and redirecting the water to another local application. This action does not necessarily increase the amount of water in the water supply, but it enables conserving higher-quality water for appropriate uses. Additionally, as a local water source, municipal recycled water can:

- Be an additional water source, possibly offsetting or delaying obtaining additional freshwater supplies.
- Be a drought-resistant water supply.
- Provide an alternative for treatment and disposal of wastewater.
- Reduce overall energy requirements, especially if it is replacing transferred water.
- Reduce discharge of excess nutrients into surface waters.
- Provide nutrients for crops or landscape plants.
- Support environmental habitats, such as wetlands.
- Be used as the water supply for an injection well barrier to control saltwater intrusion.

Recycled water is integrated into California's water supply through both unplanned applications, such as discharge into a stream with a subsequent reuse, or through planned projects. Unplanned reuse occurs when treated wastewater is discharged — usually into a surface water body — and there is no prearranged agreement or intention that the producer would maintain control of the effluent. The downstream reuse can be an environmental benefit by supplementing river flow for wetland or aquatic habitat, or a withdrawal by a downstream river water user. In the case of the latter, the wastewater discharge is regulated to protect the public health for the downstream beneficial user (Recycled Water Task Force 2003).

Planned recycled water projects are developed by water and wastewater suppliers for potable and non-potable uses (Figure 12-3). Non-potable reuse includes any application not involving drinking water for human consumption, such as landscape or agricultural irrigation, commercial applications like car washes or dual-plumbed office buildings, or industrial process such as oil refineries or cooling towers. Potable reuse results in augmentation to drinking water supplies, and it can be either direct or indirect. Direct potable reuse is treated water conveyed directly from the wastewater treatment plant to the drinking water supply lines. Indirect potable reuse is treated water from the wastewater treatment plant discharged into recharge basins to infiltrate into groundwater aquifers or into surface water reservoirs used for drinking water supply. Because seawater intrusion barriers typically result in groundwater recharge, they are considered a form of indirect potable reuse.

PLACEHOLDER Figure 12-3 Potable and Non-Potable Municipal Recycled Water

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Water discharged from a wastewater facility may still be reused even if it is not a planned action, as shown in Figure 12-2. Typically, treated wastewater is discharged into rivers and streams as part of permitted disposal practices. Discharged water then comingles with the stream or river that may be a water source for downstream communities or agricultural users. When a downstream entity withdraws water from the stream, a portion of that water is treated wastewater from an upstream discharge that has comingled with the ambient stream flow. Estimates from California Water Plans prepared in the 1980s indicated that between 86 percent and 100 percent of wastewater discharged in Central Valley hydrologic basins at the time was indirectly reused in this manner. Comingling of recycled water also occurs when it is used to recharge existing groundwater supplies (see Figure 12-2).

Treated wastewater can also be discharged to the ocean or other saline water bodies. This water usually is considered no longer practically available for reuse and is referred to as "irrecoverable water." The State recognizes recycling projects that capture municipal wastewater in coastal areas that would otherwise become irrecoverable water as providing "new water" supply. An estimated 0.9 million to 1.4 million acre-feet (af) per year (af/yr.) of "new water" could be realized by 2030 through recycling municipal wastewater that is discharged into the ocean or brackish bays (Recycled Water Task Force 2003). Because discharges to the ocean or brackish water bodies support few, if any, downstream beneficial uses, such discharges are excellent sources of wastewater for future recycling efforts (Recycled Water Task Force 2003). These projects may also support energy-efficient water supply strategies because they more fully utilize the energy already expended to treat the water to disposal levels that would otherwise be discharged to irrecoverable sources.

An additional consequence of increasing direct municipal recycled water use is that the volume of water discharged into streams may be reduced, potentially adversely affecting downstream water rights or instream beneficial uses. Recognizing this, the CWC requires that prior to making any change in the point of discharge, place of use, or purpose of use of treated wastewater, the SWRCB review potential changes to ensure potential impacts on beneficial uses are considered before authorizing a change in the permitted discharge of municipal wastewater (CWC Section 1211).

Recycled Water Use in California

Continued integration and expansion of recycled water into California's water supply options are necessary to support meeting future demands despite uncertain climactic conditions. Language recognizing the importance of recycled water in meeting future water demands is included in State law: "It is hereby declared that the people of the state have a primary interest in the development of facilities to recycle water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future water requirements of the state" (CWC Section 13510). The state reinforces this declaration by stating in the CWC that under certain conditions the use of potable water for nonpotable purposes is a waste or unreasonable use of water if recycled water is available (California Water Code Section 13550 et seq.). This has been the basis for the past several decades in California for encouraging recycled water for non-potable uses, especially for industrial and irrigation applications.

Several important actions involving municipal recycled water have occurred (or are in process) since the 2009 update of the California Water Plan. These include:

- Completion of the 2009 Municipal Wastewater Recycling Survey through a joint effort by the SWRCB and the California Department of Water Resources (DWR).

- The SWRCB's adoption of the Recycled Water Policy in 2009.
- CDPH 2011 release of draft regulations for groundwater replenishment with recycled water.
- California Public Utilities Commission (CPUC) release of its Recycled Water Policy Framework for Investor-Owned Utilities.

This section addresses past and current water recycling in the state, as well as each of the important actions involving municipal recycled water.

History of Recycled Water in California

Municipal recycled water has been used beneficially in California for more than 100 years. In the earliest applications, farms located near urban areas in this drought-prone state used effluent from municipal wastewater treatment plants. By 1910, 35 sites were using municipal recycled water for agriculture purposes. From 1932 to 1978, San Francisco's McQueen Treatment Plant, the first documented California treatment facility dedicated to treating recycled water (RMC Water and Environment 2009), supplied recycled water for irrigation in Golden Gate Park.

In 1952, 107 California communities were using municipal recycled water for agricultural and landscape irrigation. Following a national initiative to upgrade and improve the level of wastewater treatment in the 1970s, the uses of municipal recycled water applications began to diversify. Beneficial uses of California's recycled water now include landscape, agricultural, and golf course irrigation; commercial and industrial applications; environmental enhancement; groundwater recharge; and lake augmentation.

Current Recycled Water Use in California — the 2009 Survey

Statewide surveys conducted since 1970 quantified annual volumes of municipal recycled water use and have shown a steady increase in the amount and types of uses (Figure 12-4). These surveys accounted for only planned reuse with recycled water delivered directly to users or to groundwater recharge facilities. For the calendar year 2009, the SWRCB and DWR conducted a survey of agencies involved with the treatment, conveyance, or beneficial reuse of domestic wastewater as recycled water. The survey results identified 669,000 af of treated municipal wastewater that were beneficially reused in California in 2009, classified according to 11 beneficial uses (State Water Resources Control Board 2012). Beneficial uses in the 2001 and 2009 recycled water surveys, as well as historical uses, are shown in Figure 12-5. Indirect potable reuse by adding recycled water to reservoir drinking water supplies and direct potable reuse do not currently occur in California. As part of SB 918 (covered later in the chapter), the California Department of Public Health (CDPH) will investigate the feasibility of developing water recycling criteria for direct potable reuse in California.

PLACEHOLDER Figure 12-4 Municipal Recycled Water Use in California Since 1970

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 12-5 Changes in California's Recycled Water Beneficial Uses

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Recycling of municipal wastewater occurs throughout California (Figure 12-6). Only seven of the state's 58 counties do not have identified recycling projects. In general, the highest countywide volumes of recycled water occur in parts of the state where local water resources are strained, population densities are high, or wastewater disposal is problematic (Figure 12-7).

PLACEHOLDER Figure 12-6 Municipal Recycled Water Use by County in 2009

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 12-7 Regional Variations in Beneficial Uses of Municipal Recycled Water in 2009

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

The 2009 Municipal Wastewater Recycling Survey identified 210 recycling systems, directly involving almost 300 agencies in some aspect of recycling municipal wastewater in the state. These projects ranged in size from less than 50 af to more than 86,000 af in 2009, and involved many levels of complexity, from direct agricultural reuse to multiple levels of treatment and agency involvement. These projects were funded by local water suppliers, customers, and state or federal grants and loans obtained through individual or integrated regional water management (IRWM) funding applications.

Potential Recycling in 2020 and 2030

How much water will California be able to recycle in the future? Various future recycled water goals and mandates have been developed by State agencies (Table 12-1), but to date they have not been met. To establish achievable targets, DWR reviewed recycled water use projections included in 2010 urban water management plans (UWMPs), which are required to be prepared by urban water suppliers providing more than 3,000 af annually or having more than 3,000 service connections. UWMPs are discussed more in Chapter 3 of this volume, "Urban Water Use Efficiency."

PLACEHOLDER Table 12-1 Recycled Water Statewide Goals and Mandates

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Using the data from the 2009 Municipal Wastewater Recycling Survey and the UWMPs, DWR estimates that the 2020 and 2030 targets for statewide municipal water recycling should be established at 1,000,000 and 1,300,000 af. No recommendations are made to modify the existing goals or mandates (California Department of Water Resources 2013b). Achieving these new targets would require identifying new opportunities for reusing California's water resources. California's uses of recycled water have diversified over time (see Figure 12-5) and are expected to continue increasing as water resources are more constrained and as people become more knowledgeable about water reuse. Local water suppliers are assessing opportunities for indirect and direct potable reuse of highly treated recycled water as a way of augmenting and "drought-proofing" local supplies, as well as expanding existing irrigation and industrial applications.

The recycled water community is also placing greater emphasis on matching wastewater treatment levels to water quality requirements for the planned reuse, referred to as “fit for purpose” (U.S. Environmental Protection Agency 2012). This concept is where more rigorous treatment (and more energy-intensive processes) is reserved for uses with higher human or food production contact to minimize pathogen or chemical of emerging concern contact. Conversely, less-treated wastewater has been safely used for decades in many agricultural reuse applications, which is the largest category of recycled water use in California. Greater reuse of secondary-treated wastewater in agriculture and environmental settings, where additional “natural treatment” can augment wastewater plant treatment, may provide additional opportunities for meeting the newly established 2020 and 2030 recycled water targets. Finally, water suppliers may determine that having available multiple levels of treated wastewater may support increased integration of recycled water use into their water supply portfolio. West Basin Municipal Water District is very successfully providing multiple water quality levels of recycled water to its customers to meet specific needs of its diverse customer base.

Tracking the State’s success in increasing use of recycled water and achieving identified goals, targets, and mandates would require conducting future recycled water surveys. Collection of actual recycled water use data in a manner consistent with approaches used in previous recycled water surveys will facilitate monitoring progress. However, completing a voluntary recycled water use survey using the existing methodologies is a labor-intensive effort. Initial discussions are under way to identify more efficient data collection approaches using mandatory, electronic reporting. Because of the complexity of recycled water producers, wholesale and retail agency, and end user relationships, any electronic reporting mechanism will have to be coupled with expert review and compilation of data to avoid missing or duplicating data in surveys.

Recycled Water Use Policies, Regulations, Responsibilities, and Funding

As the treatment level of municipal wastewater increases from primary to secondary, tertiary, or advanced, the permitted uses of recycled water increase. State policies and regulations are in place to increase the use of recycled water in a manner that is protective of human and environmental health. State regulations mandate that producers and users of recycled water comply with treatment and use restrictions to protect public health and water quality.

In general, the levels of treatment for recycled water use are based on levels of human exposure and pathways of exposure leading to infection. The required levels of treatment are specified in Title 22 of the California Code of Regulations (CCR) (Division 4, Chapter 3, Section 60301 et seq.). The Title 22 regulations also specify monitoring and reporting requirements and on-site use area requirements. For example, municipal wastewater that has completed tertiary treatment can be used to irrigate school yards, parks, and residential landscape and may be suitable for industrial applications or use in office and institutional buildings for toilet flushing. Wastewater that has been treated to secondary levels is generally suitable for uses that do not include contact with people or unprocessed food crops, such as agricultural irrigation of animal feed crops. The treatment to serve these special needs is not governed by Title 22 regulations.

Aside from the need to protect human health, there are special water quality needs for uses in agriculture or industry to grow crops or manufacture products. Higher levels of treatment may be needed for some industrial applications. Some agencies are able to provide multiple levels of recycled water treatment for various customer uses.

Recycled Water Roles

The current framework for regulating municipal recycled water has been in place since the 1970s. As established in State law, primary authority for overseeing municipal recycled water is divided between the SWRCB, including the nine regional water quality control boards (RWQCBs), and the CDPH. A memorandum of agreement between the two agencies documents this arrangement and clarifies the roles of the agencies. The CDPH regulates public water systems and sets standards for wastewater reuse to protect public health by adopting water recycling criteria based on water source and quality and by specifying sufficient treatment based on intended use and human exposure. The treatment objective is to remove pathogens and other constituents, making the water clean and safe for the intended uses. The SWRCB, through the RWQCBs, has the roles of permitting and providing ongoing oversight authority for water recycling projects. The permits incorporate applicable CDPH Title 22 requirements and specify approved uses of recycled water and performance standards.

Four other state agencies are directly involved with municipal recycled water issues in California and implement various sections of State law: DWR, the CPUC, the California Department of Housing and Community Development (HCD), and the California Building Standards Commission (CBSC). Statutes governing municipal recycled water are currently contained within the CWC, the California Health and Safety Code, the California Government Code, the Public Resources Code, and the Public Utilities Code, and regulations are in various subdivisions (titles) of the CCR. State agency roles and responsibilities are summarized in Table 12-2.

PLACEHOLDER Table 12-2 State Agency Recycled Water Roles and Responsibilities

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

In addition to the statewide agencies, local city and county officials also have a regulatory role affecting municipal recycled water projects. In some cases, the CDPH can delegate responsibilities to local officials if local sponsors of municipal recycled water projects agree with the delegation.

Recycled Water Use Statutes, Regulations, and Policies

Since the 1970s, various statutes, regulations, and policies have been enacted and developed to address recycled water generation and use. Table 12-3 highlights some of them. Additionally, there are several new and pending regulations, which are discussed here. The following discussion is based on conditions in early 2013. Some revisions to State statutes have been introduced into the Legislature to consolidate and streamline existing recycled water laws to facilitate uniform implementation.

PLACEHOLDER Table 12-3 Important Recycled Water Policies and Regulations

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Recycled Water Policy of 2009

In 2009, the SWRCB adopted the Recycled Water Policy to address issues of concern for permitting recycled water and protecting water quality, including salinity management, regulation of incidental runoff, and monitoring and regulation of chemicals of emerging concern. The policy (State Water Resources Control Board 2009b) calls for managing basins or subbasins through stakeholder involvement and implementation of salt and nutrient management plans and regulating incidental runoff through waste discharge requirements and best management practices. It also prioritizes approval of groundwater recharge projects utilizing municipal recycled water treated by reverse osmosis.

The policy was modified in 2013 to incorporate science advisory panel recommendations (State Water Resources Control Board 2010) on monitoring chemicals of emerging concern. Chemicals of emerging concern are new classes of chemicals in the environment — such as pharmaceuticals, currently used pesticides, and industrial chemicals — that could have adverse aquatic and human health effects and for which there is less toxicological information than there is for chemicals that have been longer used and studied. These chemicals have the potential to be present in recycled water, which is why the SWRCB convened the scientific panel and modified the Recycled Water Policy to address monitoring requirements for chemicals of emerging concern in certain types of recycled water projects.

Senate Bill 918

SB 918 was enacted in 2010 and focuses on the issues of indirect and direct potable reuse. It requires CDPH adoption of uniform water recycling criteria for indirect potable reuse for groundwater recharge in 2013 and surface water augmentation in 2016. It also requires the CDPH, by the end of 2016, to investigate and report to the Legislature on the feasibility of developing uniform water recycling criteria for direct potable reuse. The CDPH is required to convene an expert panel to advise it on the development of criteria for surface water augmentation and the feasibility of direct potable reuse.

The current Title 22 regulations provide that requirements for groundwater recharge projects using recycled water will be determined on a case-by-case basis. With the aim of adopting uniform statewide regulations, draft groundwater recharge regulations have been in place since the mid-1980s. They have evolved over time, incorporating experience with ongoing projects and new scientific information.

In November 2011, the CDPH released revised draft regulations addressing groundwater replenishment using recycled water from domestic wastewater sources, for aquifers designated as a source of drinking water. In December 2011, the CDPH held workshops throughout the state and requested written comments from all interested parties. The CHPH has reviewed the comments and anticipates releasing a revised draft in spring 2013. The proposed regulations would replace the existing case-by-case regulations. Through SB 918 (2010), CWC Section 13562 requires the CDPH to adopt revised groundwater replenishment regulations by Dec. 31, 2013. However, it is unlikely this deadline will be met, because the CDPH has not received the additional resources necessary to meet the deadline in SB 918. Nevertheless, proposed groundwater replenishment (and surface water augmentation) projects continue to move forward.

The proposed groundwater recharge regulations seek to protect public health for projects utilizing indirect reuse of recycled water to replenish drinking water basins, by establishing criteria that cover:

- Source water control.
- Potential risks associated with pathogenic microorganisms, regulated contaminants, and unregulated contaminants.
- Effective natural barriers and multiple treatment barriers.
- Ongoing monitoring of recycled water and groundwater.
- Effective treatment processes.
- Time to identify and respond to failures.
- Review, reporting, and notification processes.

Recycled Water Policy Framework for Investor-Owned Utilities

The CPUC is in the process of developing a comprehensive policy framework to cover recycled water projects, production, and recycled water use for the investor-owned water and sewer utilities that it regulates. This action, required under the CPUC's Order Instituting Rulemaking 10-11-014, applies to investor-owned utilities with a customer base of 2,000 or more connections. The goal of the policy framework is to facilitate the cost-effective use of recycled water where it is available or can be made available and to reduce the barriers to collaboration between wholesalers and retail recycled water purveyors. The policy framework is expected to provide guidance to investor-owned water and sewer utilities that are in a position to identify, evaluate, and pursue opportunities to add recycled water to water supply portfolios. The policy framework will take into account the most recent State policy and legislation for the production, delivery, and use of recycled water and will encourage interagency coordination and collaboration in the implementation of these policies.

Recycled Water Use Funding

Recycled water projects are funded directly by local water agencies and water users through rates, bonds, or rebates. Individual water users may also pay for projects that directly benefit them, such as an industrial facility installing on-site or off-site infrastructure to receive recycled water or implementing a process modification. Local agencies take the lead in identifying, analyzing, and prioritizing the water resource projects in their jurisdictions to help achieve their identified goals. They then proceed with the best option to implement their identified projects. Once projects are constructed, revenue from the sale of recycled water, revenue from the sale of potable water, and tax assessments are options for operation, maintenance, and debt service financing.

Other funding options include obtaining grants or loans from both State and federal sources, including the sources listed below.

- **IRWM Grant Program**, administered by DWR. The IRWM grants (funded by Proposition 84) are used by communities in IRWM regions to implement water supply and management projects. Water recycling is one of many strategies that may be considered by IRWM regions in developing their water resource management portfolios.
- **Water Recycling Funding Program**, administered by the SWRCB. This program provides low-interest financing and grants to local agencies (funded by a variety of sources, including Proposition 13). Water recycling is a key objective in the SWRCB's *Strategic Plan Update 2008-2012* (State Water Resources Control Board 2008), which identifies priorities and direction for the SWRCB and its nine RWQCBs.
- **Clean Water State Revolving Fund**, administered by the SWRCB (and funded by the federal Clean Water Act and State bonds). This program provides low-interest financing primarily for wastewater collection, treatment, and disposal, but it also funds recycling projects.

- **Title XVI,** administered by the U.S. Bureau of Reclamation. This federal program (authorized by Title XVI of Public Law 102-575) funds water reclamation and reuse projects throughout the western United States.

With State budget constraints, it is likely that additional sources of funding will be limited in the future. This is a challenge, because implementation of recycled water projects often requires significant capital outlay, which many water suppliers are not able to fund without outside resources. However, given the importance of a reliable water supply to the state's economy, legislative support of providing additional funding for recycled water projects is a critical component of continued recycled water development.

Later in this chapter, the subsection "Affordability" describes sharing costs, regional approaches, planning considerations, and actions that could support implementation costs.

Potential Benefits

Water recycling provides many benefits to local and statewide water supply reliability. Municipal recycled water increases local supplies, supports drought preparedness, mitigates climate change effects, provides environmental benefits, and can reduce energy consumption by lowering dependence on imported supplies.

Local Supply

Municipal recycled water has the advantage of being locally generated and reused. The availability of additional local supplies can provide resource-limited communities with additional options for meeting water supply demands. Areas with constrained or declining groundwater supplies or heavy dependence on imported water may realize significant benefit from appropriate reuse of treated municipal wastewater. Recycled water may provide more cost-effective water self-sufficiency options than other resource development alternatives. It can also provide additional water resources to address increased demands from population growth.

Drought Preparedness

Establishing recycled water capacity provides a more reliable water supply resource for water managers to access during drought cycles. Municipal recycled water as a water supply has less variability than traditional resources because domestic water disposal continues even during droughts. Wastewater production will decrease during a drought as households and commercial and industrial facilities conserve, but some wastewater generation will still occur.

Climate Change

Climate change is expected to increase atmospheric temperatures, resulting in a more variable precipitation regime and declining snowpack (California Department of Water Resources 2008). Consequences of the warming climate are anticipated to reduce water resource supply and increase water demand for urban, agricultural, and environmental uses, with a concurrent reduction in water supply availability and reliability.

Municipal recycled water will contribute to sustainability for urban water supplies facing changing climate conditions, particularly where local water supplies are limited. As a source of water for groundwater recharge, recycled water can support climate change planning. Groundwater basins and aquifers have the potential to store significant amounts of water from a variety of sources, potentially including stormwater and treated wastewater for later recovery. The use of recycled water to recharge groundwater basins can address climate change adaptation:

- Wastewater discharges represent a potential source of additional water that is currently underutilized or not utilized.
- Groundwater recharge provides a practical storage solution.

As stated earlier, the CDPH has proposed draft regulations for the use of recycled water for groundwater recharge.

Energy Savings

Implementing municipal water recycling could reduce energy consumption, which may also support California's climate change mitigation efforts. Combustion of fossil fuels at power plants is a major source of greenhouse gas (GHG) emissions. The water sector uses a significant amount of the energy produced by those power plants, especially for the conveyance of water from its source to its use. Water recycling can provide a lower-energy source of local water compared with importing water from other regions and desalination of ocean water or brackish waters. Energy savings are greatest when recycled water is used in close proximity to wastewater treatment sources and when additional treatment is not required beyond the treatment needed for wastewater disposal.

Recycled water used for most urban applications requires tertiary treatment, which requires a greater amount of energy and reduces the potential GHG savings. However, in many cases, tertiary treatment is required to protect public health or the environment when wastewater is discharged to streams. In such cases, to take the further step to recycle the wastewater for urban uses, it is necessary only to install infrastructure to convey the recycled water to end users. The energy and GHG emissions associated with tertiary treatment are allocated to pollution control and environmental protection, and the energy and GHG emissions associated with conveyance are allocated to the water supply function of water recycling.

Energy savings realized by implementing a recycled water project depend on multiple factors, including the source of the water offset by the recycled water and the amount of increased treatment above disposal needed to reuse the water. Research is also ongoing to develop lower-energy recycling methods, which would in turn reduce the GHG generation during the water recycling process. Overall, it is assumed that implementing recycled water would provide energy use benefit by developing local resources versus importing fresh water.

Potential Costs

Augmenting statewide municipal recycled water funding, even in light of current statewide budget issues, is a long-term benefit because it develops local, reliable water supplies. The costs to implement recycled water projects vary based on the amount of water to be treated, treatment requirements, infrastructure needs, project planning, permitting, and financing. As a result, project costs can vary widely, as described further below.

Overall Costs

California's Recycled Water Task Force (2003) estimated that between 2003 and 2030, an additional 1.4 million to 1.7 million af of additional wastewater could be recycled annually in California, based on growth in available wastewater and increased percentage of wastewater recycling. Of this, 0.9 million to 1.4 million af (62 percent to 82 percent) of the additional recycled water would be from discharges that would otherwise be lost to the ocean, saline bays, or brackish bodies of water (Recycled Water Task Force 2003). To add 1.4 million to 1.7 million af per year of recycled water, the task force estimated that a capital investment of between $9 billion and $11 billion would be required (in 2003 dollars) (Recycled Water Task Force 2003). This amount would be the incremental capital cost above the cost of wastewater treatment for discharge to a water body.

Given the variability of local conditions and their effect on treatment and distribution costs, the current estimated range of capital and operational costs of water recycling range from $300 to $1,300 per af of recycled water, but in some instances costs are above this range. The upper end of the current unit costs for recycled water projects comes from cost estimates recently prepared for two Southern California projects, in San Diego and Oxnard. Costs per af for those projects are estimated to be between $1,191 and $1,900 (Fikes 2012; Wenner 2012). These are urban projects and are reflective of higher-end projects, as well as the increasing costs of implementing recycled water projects. Therefore, for planning purposes, the State should consider that overall costs to reach the Recycled Water Task Force potential estimate will be at the higher end of the estimate range, if not beyond this.

Increased focus on matching water use to water quality is an approach to implement more cost-effective projects while attempting to lessen ratepayer impacts for these projects. In a state where between 70 percent and 80 percent of developed water is used for agriculture, projects that can convey secondary effluent to agricultural users and develop cooperative solutions could be a cost-effective way to meet water resource needs. Overall, the actual cost of recycled water projects will depend on the quality of the wastewater, the level of treatment required, the proximity of potential users to the sources of recycled water, and user costs associated with required upgrades or operational modifications. Uses that require higher water quality or have greater public health concerns, or both, will incur higher costs.

The cost to install new distribution systems is a major obstacle to the expansion of water recycling. Assessing costs of implementing recycled water programs should consider not only the cost of municipal infrastructure and its operation and maintenance, but also the cost to users. In particular, larger industrial, agricultural, or commercial users that may need on-site modifications to maintain a separate water system, including physical barriers for backflow prevention, or process modification to utilize a different water quality. In addition, a user may have additional operating costs for recycled water use as that user integrates recycled water into its water supplies.

Because recycled water is not classified as potable, regulatory constraints prohibit conveying recycled water and potable water in the same pipelines. Under current regulations, recycled water must be conveyed in a separate purple pipe distribution system that is labeled and readily distinguished from potable water lines. The cost to install new purple pipe distribution mains from treatment plants to users can exceed the costs of obtaining alternate water sources or projects — including, in some cases, the cost of potable reuse projects. As a consequence, extension of purple pipe systems to areas near treatment plants can be more cost-effective than extending infrastructure and service to more distant users.

Distribution system cost can be an obstacle when evaluating the feasibility of supplying recycled water to large numbers of users or users more distant from urban wastewater treatment plants. Some water agencies have constructed satellite water recycling facilities to provide recycled water at locations near large concentrations of use.

How cost is a potential issue to increasing recycled water use in California is discussed further in the next section.

Individual User Costs

Additional costs that individual recycled water users may need to incur to receive recycled water include installing dual plumbing, modifying facility processes to use water of a different quality, and implementing cross-connection prevention. These can be significant cost components to potential recycled water customers using both potable and non-potable water.

Cross-connections, the accidental direct contact between potable and non-potable water systems, can contaminate potable water systems. Air gaps, valves, or other controls are installed to prevent cross-connections because of inadvertent pipe connections, pressure loss, or other failures. Specific requirements vary by the water supplier or governmental agency. State regulations to protect public potable water systems from contamination by non-potable water are in CCR Title 17 adopted by the CDPH.

The California Plumbing Code specifies protections to prevent potable water lines on the property of users from contamination. Its provisions governing dual plumbing in buildings were adopted in California in 2009. These codes established statewide standards to install both potable and recycled water plumbing systems in commercial, retail, and office buildings; theaters; auditoriums; condominiums; schools; hotels; apartments; barracks; dormitories; jails; prisons; reformatories; or other structures as determined by the CDPH. Some potential recycled water customers have faced challenges working with local inspectors to implement dual-plumbed systems, but these issues are expected to decrease as the systems become more common.

Major Issues

There are many issues involved in planning and implementing recycled water projects. However, based on the many successful projects in California, potential obstacles are not insurmountable. Awareness of potential issues and sound planning practices to address or prevent negative impacts are key components of successful project development. Successfully implemented projects have also included early involvement of affected agencies, potential recycled water customers, other stakeholders, and representatives of public interests.

Identifying and planning successful approaches to issues that could hinder the implementation of increasing recycled water use both locally and statewide is critical for continued growth. The Recycled Water Task Force (2003) identified 26 recycled water “issues, constraints, and impediments” and provided recommendations to address them. More recently, three efforts conducted since Update 2009 addressed issues (also referred to as barriers or challenges) facing increased municipal recycled water use. These efforts were:

- *Integrated Water Resources Plan: 2010 Update* (Metropolitan Water District of Southern California 2010).
- *Draft Commercial, Institutional and Industrial Task Force Water Use Best Management Practices Report to the Legislature* (California Department of Water Resources 2013a).
- *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater* (National Research Council 2012).

Input from these documents supported development of the issue discussions included in this section. As part of future recycled water planning, a comprehensive review of the Recycled Water Task Force recommendations, in coordination with these more recently completed efforts, would provide guidance to DWR and the recycled water community on prioritizing future actions.

The issues addressed below are commonly confronted in planning and developing local and regional recycled water projects. DWR (and other State agencies directly involved with recycled water) will support local efforts by preparing applicable statewide recycled water planning documents. This will include reviewing the National Research Council's recommendations (2012) and other applicable documents (e.g., National Water Research Institute 2012) and integrating those that are applicable to California.

Affordability

The affordability of recycled water has to be viewed from various perspectives, such as those of agencies implementing recycled water projects, users of recycled water, suppliers of potable water whose revenue may be affected by recycled water use, and sewer and potable water ratepayers who may see their rates affected by recycled water use. The costs of recycled water projects may include: additional treatment above current wastewater treatment, disposal of treatment byproducts, storage and pump facilities, and recycled water pipeline distribution systems. In addition, there may be on-site costs at user sites for specialized treatment of the recycled water, including on-site plumbing, cross-connection control devices, and potential modification of commercial or industrial processes to accommodate recycled water. The responsibility for payment of these costs depends on sources of revenue or financial assistance and how agencies agree to share costs based on the perceived beneficiaries.

The common reference point for water suppliers and users is what they currently pay for alternative water sources, such as potable water, or what agencies will have to pay in the future for new water supplies. Water suppliers in California are often dependent on other wholesale suppliers for their water supply. Prices for water often are set to recover costs from past projects and do not reflect the more expensive costs of new water supplies. Thus, prices are not a good benchmark for the true economic cost of new water supplies. New freshwater supplies are often developed at the regional or state level, whereas recycled water projects are often developed at the sub-regional or local level. It is difficult for any one water supplier or user to see the total water supply picture from the standpoint of costs.

Much of the water provided by federally funded projects is provided at discounted prices. Artificially low rates discourage adoption of water recycling and similar conservation programs. Consequently, there is growing recognition that pricing should more closely reflect the true costs to provide water and thus encourage more efficient use of existing water supplies. As stated in the National Research Council's 2012 report on national water recycling, "Current reclaimed water rates do not typically return the full cost of treating and delivering reclaimed water to customers." Water pricing issues need to be considered early in the planning process for recycled water and thoroughly vetted with potential customers.

Some benefits or costs can be difficult to quantify and, even though real, are accrued indirectly such that they are not reflected in project costs. Recycled water has a benefit of reliability during droughts, but the monetary benefit accrues to the general economy and not to water suppliers. There may be a water quality benefit to reusing water instead of discharging treated wastewater into a river.

Economic tools can provide a quantification of many indirect costs and benefits, and a methodology called an economic analysis can be used to compare recycled water and other water projects on an equal basis by looking at total costs and benefits to society as a whole. When economic analysis finds recycled water to be cost-effective compared with alternative water supplies, the challenge should then be to allocate costs according to beneficiaries and to use financial incentives, such as regional rebates or State and federal loans and grants, to encourage local water suppliers to build recycled water projects.

Interagency cooperation can be a way to allocate costs according to beneficiaries and to achieve multiple objectives. Recycled water can improve regional water reliability and offset potable water that can be used in other areas. Regional water supplier partners can help local recycled water projects by contributing to construction and operation costs reflecting the regional benefits. Because of high initial infrastructure costs, many California communities are developing cooperative recycled water projects. These projects are developed and implemented locally to best serve the local needs. Projects have been developed where one community provides wastewater to another that then treats it to recycled water standards and distributes it. Another institutional arrangement involves a wastewater agency producing recycled water and a partnering water agency distributing it.

Advancements in water recycling treatment technology may bring down costs in the future, especially for indirect and, potentially, direct potable reuse, where high levels of treatment are often required. Another way of reducing costs is to incorporate purple recycled water pipelines in new developments at the same time as potable water lines are being installed. Long-range planning can anticipate where future recycled water users should be.

Nevertheless, dedicated recycled water distribution systems are costly. Adding recycled water to sources of drinking water (e.g., aquifers or surface reservoirs) eliminates the need for dual distribution systems. Introducing highly treated recycled water directly into potable water pipelines could also eliminate the need for separate recycled water lines. Groundwater recharge is widely practiced in California, but suitable aquifers are not available everywhere. Indirect potable reuse by augmenting surface drinking water reservoirs with recycled water and direct potable reuse are currently not allowed in California, but such practices would give communities more flexibility in how recycled water could be used at potentially lower cost than non-potable reuse through separate recycled water pipelines. SB 918 established a schedule for the CDPH to evaluate surface water augmentation and adopt regulations and to evaluate direct potable reuse and report to the Legislature.

The availability of local funding sources continues to challenge the implementation of new projects or the expansion of existing projects. Where a recycled water project is found to be cost-effective from an evaluation of all costs and benefits from society's perspective, but more expensive than alternatives from a local perspective, there is a role for regional, State, and federal financial assistance to encourage the optimum water resource solution. The primary source of State funding has been the Water Recycling Funding Program administered by the SWRCB, which provides low-interest loans and grants to local agencies. DWR administers the IRWM Grant Program. Water recycling is an RMS that must be considered by an integrated regional water management plan (IRWMP) and may be utilized as an active component of the plans to help a region meet water management goals and objectives. Inclusion of wastewater agencies in the IRWM process will facilitate the identification of municipal recycled water projects as viable water supply projects and facilitate the interaction of water and wastewater agencies to identify mutually beneficial solutions to common issues. Water recycling projects identified in IRWMPs to be a key strategy may qualify for IRWM grant funding. The federal government, through the U.S. Bureau of Reclamation, has been a major contributor of grants and loans to recycling projects in California, primarily through the Title XVI program.

Water Quality

Water quality criteria for recycled water, established by the CDPH, define water quality and treatment requirements to protect public health for most expected uses of recycled water. RWQCBs establish water quality requirements to protect the beneficial uses of surface and groundwater bodies. Under current regulations, RWQCBs issue the waste discharge or water reclamation permits to recycled water producers, distributors, and users. These permits incorporate water quality and monitoring requirements for recycled water projects, including health department criteria to protect public health and any site-specific requirements for protecting water quality.

Recycled water quality is to protect environmental and human health in order to support current uses and long-term sustainability. Recycled water quality issues include:

- Pathogen content (primarily bacteria and viruses).
- Salinity.
- Nitrogen compounds.
- Heavy metals.
- Organic and inorganic substances (often of commercial and industrial origin, but also pharmaceuticals and personal care products, household chemicals and detergents, fertilizers, pesticides, fungicides, and hormones), including chemicals of emerging concern.

Chemicals of emerging concern, described earlier in this chapter within the section about the Recycled Water Policy, are found in wastewater and may occur in recycled water at very low concentrations. Research is ongoing regarding potential impacts of chemicals of emerging concern in recycled water, particularly with respect to effects on human health or the environment. Currently, there are no established regulatory limits for chemicals of emerging concern, but some monitoring is required by the CDPH and the SWRCB as a precaution for protection of human health and the aquatic environment.

The SWRCB's expert panel on chemicals of emerging concern (State Water Resources Control Board 2010) provided recommendations, based on available information, for constituents to be included in required monitoring of various types of recycled water projects. These recommendations have been incorporated into the Recycled Water Policy. As additional information becomes available, future changes can be made to regulations and policies to protect California's water resources while supporting implementation of new projects.

The Recycled Water Policy encourages the development of salinity and nutrient management plans. These plans address salinity and nitrogen issues, including changes that may occur with the use of recycled water. Therefore, implementation of a recycled water program may be enhanced by the parallel development of a salinity and nutrient management plan. In addition to water quality being protective of human and environmental health, aligning water quality to end use is a key component of recycled water planning and implementation (see Chapter 17 within this volume, "Matching Water Quality to Use"). The planned end uses and commercial/industrial application compatibilities are crucial recycled water considerations. In many cases, recycled water is integrated into existing processes. Most commercial and industrial applications are sensitive to water quality, and recycled water typically has more minerals and organic content than many available alternative supplies. Subtle changes in water quality, such as increases or decreases of certain minerals or chemical species, can dramatically change the suitability of recycled water or the treatment requirements for use in an industrial process. Many water quality concerns associated with recycled water can be and are addressed with additional treatment by the water utility, on-site treatment, or other water management practices. These additional efforts have to be considered during recycled water planning, along with financial impacts and responsibilities.

Public Acceptance

Public acceptance of recycled water projects is critical for their success. Water quality and cost factors are two issues often raised by the public. Integrating public input into the project planning phase has been a successful approach for many agencies.

In general, there is public acceptance and support for most non-potable recycled water applications, such as agricultural and landscape irrigation, where there is a lower degree of direct human exposure. Public acceptance can be lower for projects with more direct links between recycled water and human consumption or contact. A factor that may raise some public concern is a perceived conflict between assurances that recycled water is safe and the necessity of regulations to protect the public from misuse. Outreach, education programs, and involvement during project planning can provide public reassurance that recycled water is adequately regulated to protect public health.

Environmental buffers — natural processes separating treated recycled water from human end uses — frequently enhance public acceptance of recycled water projects and differentiate indirect and direct potable reuse, as explained earlier. For example, public concern about mixing recycled water with groundwater appears to be partly alleviated when infiltration, percolation, and underground residence time expose the water to natural cleansing processes after engineered treatment. The actual benefit of environmental barriers versus engineered treatment with system controls has not been fully quantified. Additional research and planning may support how environmental buffers and engineered controls are perceived by the public and implemented in future projects.

Impacts on Downstream Users

Communities that discharge wastewater to rivers and streams contribute to the ambient water available for use by downstream users. The implementation of water recycling in upstream communities would reduce the volume of such discharges, potentially reducing the volume of ambient water available for downstream reuse or fulfillment of environmental needs. In some circumstances, downstream users may have rights to the use of discharged wastewater, potentially preventing upstream communities from implementing recycling.

In the case of groundwater recharge with recycled water, the availability of groundwater downgradient may be increased, but there may be water quality impacts. Whether for storage or planned indirect use, the discharge of recycled water to wells, infiltration sites, or other locations underlain by permeable soil and geologic materials has the potential to introduce contaminants, including salts, into potable groundwater sources and aquifers. Modern microfiltration, reverse osmosis, and disinfection practices produce exceedingly high-quality recycled water, but lingering concerns about pathogens, emerging contaminants, or other potentially unknown contaminants warrant continued research to advance the science and technology in this area. Presently, California does not approve direct potable reuse projects, that is, where recycled water is piped directly from a treatment plant into a drinking water supply.

Recommendations

1. **Review Recycled Water Task Force recommendations.** The Recycled Water Task Force presented 26 recommendations to increase water recycling in its 2003 report, *Water Recycling 2030: Recommendations of California's Recycled Water Task Force*. Significant accomplishments have resulted from implementing the task force's recommendations. With the 10-year anniversary of the completion of the task force's efforts, DWR intends to review the recommendations and prioritize progress that should occur to complete the task force's mission.
2. **Develop approaches to facilitate increasing statewide use of recycled water for agricultural and environmental uses.** DWR, in cooperation with the SWRCB and the RWQCBs, will identify obstacles to increasing agricultural and environmental reuse of recycled water, with an emphasis on applications using secondary-treated wastewater. The focus of this effort is to implement "fit for purpose" and matching wastewater treatment levels to water quality requirements for the planned reuse to support meeting the State's 2020 and 2030 targets for recycled water use.
3. **Develop a uniform interpretation of State standards for recycled water.** State agencies including the SWRCB, the RWQCBs, the CDPH, DWR, and the CPUC should develop a uniform interpretation of State standards for inclusion in regulatory programs and IRWMPs and should clarify regulations pertaining to water recycling, including permitting procedures, health regulations and the impact on water quality. It is important to recognize that uniformity in State standards does not mean uniformity in permit terms and conditions, however, as implementation should account for the variability in local conditions and local needs. Implementing this recommendation could also streamline existing regulations about recycled water. Internal and cross-training of agency staff could be a key method of accomplishing this.
4. **Review National Research Council recommendations.** The National Research Council (2012) completed a comprehensive review of how recycled water use can be expanded. This report includes numerous recommendations, as well as possible approaches to implementing them. In 2013, DWR will take the lead in working with the other State agencies involved with recycled water to determine the applicability of the recommendations to California and to develop an approach to implementing these recommendations in California, as appropriate.
5. **Continue to review opportunities for recycled water development.** DWR will continue to identify opportunities to increase statewide planning, development, and implementation of recycled water. It is intended that this will be accomplished with comprehensive statewide planning documents and regional interactions over the next few years.
6. **Incorporate wastewater agencies into regional IRWM processes.** Inclusion of wastewater agencies into regional IRWM processes will facilitate the integration of recycled water into the

water supply planning process. In addition, potential recycled water customers should be involved in the IRWM and recycled water project planning process to identify potential partnerships, assess the viability of recycled water projects, and consider future CII water quantity and quality planning.

7. **Provide dedicated recycled water funding.** The State Legislature is urged to provide additional funding dedicated to planning and implementing recycled water projects in California. Although some funds are available through IRWM grants and loans, the cost of implementing these projects can make them difficult to put forth in the existing grant processes, especially with so many water suppliers facing financial challenges. If California intends to reach its water recycling mandates and goals and support future water supply reliability to support economic growth, then additional funds dedicated to recycled water implementation will need to be provided. Additional funding sources will be needed when Proposition 84 funds are no longer available.
8. **Develop reliable electronic reporting methods for recycled water data**. To be able to monitor progress in meeting targets or achieving progress in beneficially using recycled water, there is a need for reliable and periodic data collection. Voluntary surveys have been the historic method of data collection. Mandating standardized data collection integrated with electronic reporting could facilitate the collection of data and the availability of the data for use. DWR, the SWRCB, and the CDPH should work together to accomplish this objective.

Municipal Recycled Water in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy is not discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 12-1 Recycled Water Statewide [a] Goals and Mandates

Target type [b]	Target volume (in thousand acre-feet)					Notes	Source
	2000	2010	2015	2020	2030		
Potential		1,030			2,050	Midrange of projected potential use increases above 2002 levels	Recycled Water Task Force 2003
Goal	700	1,000					Water Recycling Act of 1991
Goal			1,250				State Water Resources Control Board 2008
Goal				1,525	2,525	1 million acre-feet above 2002 [c] for 2020 and 2 million acre-feet above 2002 for 2030	State Water Resources Control Board 2009b
Goal (draft)				1,000	1,300	Based on urban water management plans (UWMPs) and 2009 Municipal Wastewater Recycling Survey data	California Department of Water Resources 2013b
Mandate				869	1,169	200,000 acre-feet above 2009 for 2020 and an additional 300,000 acre-feet for 2030	State Water Resources Control Board 2009b

[a] The actual 2009 statewide volume of beneficially reused municipal recycled water was 669,000 acre-feet.

[b] Potentials, mandates, and goals are terms used in the identified sources. They are developed using various approaches. Mandates are stronger objectives, but in this case they do not carry a defined penalty for non-attainment.

[c] The Recycled Water Policy (State Water Resources Control Board 2009b) indicates that 2020 and 2030 goals are determined relative to the 2002 recycled water levels. The 2001 and 2002 numbers are considered the same because they were based on the same data.

Table 12-2 Regulatory Agency Roles and Responsibilities for the Regulation and Use of Municipal Recycled Water

Agency	Role	Responsibility	California Code of Regulations title number
California Department of Public Health	Protects public health	• Adopts uniform recycled water criteria for non-potable and potable recycled water projects [a] • Provides recommendations for recycled water project permits • Reviews and makes recommendations on sites proposed for recycled water use • Oversees cross-connection prevention [b] • Oversees protection of drinking water sources • Regulates public drinking water systems	Titles 17 and 22
State Water Resources Control Board	Protects water quality and water rights	• Establishes general policies governing recycled water project permitting • Oversees regional water quality control boards • Provides financial assistance to local agencies for recycled water projects • Allocates surface water rights	Title 23
Regional water quality control boards (nine)	Protects water quality	• Issue and enforce permits for recycled water projects, incorporating California Code of Regulations Title 22 requirements and California Department of Public Health recommendations • Protect surface water and groundwater quality from recycled water impacts	Title 23
California Department of Water Resources	Manages statewide water supply	• Evaluates use of and plans for potential future recycled water uses through the preparation of the California Water Plan • Provides financial assistance to local agencies for recycled water projects • Adopts standards for recycled water indoor plumbing	Title 24 (California Plumbing Code, Chapter 16A, Part II)
California Public Utilities Commission	Oversees rates and revenues of investor-owned utilities	• Approves rates and terms of service for the use of recycled water by investor-owned utilities	Title 20
California Department of Housing and Community Development	Oversees building standards for dwellings, including institutions and temporary lodgings	• Adopts standards for gray water systems in residential structures • Adopts standards for non-potable water systems within buildings over which it has jurisdiction	Title 24 (California Plumbing Code, Chapter 16A, Part I; Chapter 6)
California Building Standards Commission	Oversees adoption of standards for buildings	• Adopted standards for gray water systems in non-residential structures in 2011 cycle of California Building Standards Code • Oversees the adoption of the California Plumbing Code, including provisions added by other State agencies	Title 24 (California Building Standards)

Agency	Role	Responsibility	California Code of Regulations title number
Local building officials	Oversees building design, including plumbing	• Enforce building standards, including the California Plumbing Code	Title 24
County environmental health departments	Protects drinking water systems	• Enforce cross-connection control • Review and make recommendations on proposed recycled water use sites	Titles 17 and 22

[a] As of November 2011, the California Department of Public Health has adopted regulations in Title 22 for non-potable use of recycled water, but not for potable reuse projects. Senate Bill 918 requires the department to adopt uniform water recycling criteria for indirect potable reuse projects involving groundwater recharge and surface water augmentation.

[b] The California Department of Public Health may delegate some responsibilities for review of new sites and cross-connection control to the local county health departments with the permission of the local recycled water provider.

Table 12-3 Important Recycled Water Policies and Regulations

Year	Action	Organization	Summary
1984	Water Quality Order 84-7	State Water Resources Control Board	Pursuant to California Water Code, Section 13142.5(e), in cases where discharges of wastewater to the ocean are proposed in "water-short" areas, the report of waste discharge should include an explanation as to why the effluent is not being recycled for further beneficial use.
2001	Assembly Bill 331, Recycled Water Task Force	California Assembly	This bill established a 40-member Recycled Water Task Force to evaluate the current framework of State and local rules, regulations, ordinances, and permits to identify the opportunities for, and obstacles or disincentives to, increasing the safe use of recycled water. The task force was composed of individuals representing federal, State, and local government; public health professionals; private sector entities; environmental organizations; the University of California; internationally recognized researchers; and public interest groups. The task force was a cooperative effort of DWR, the State Water Resources Control Board, and the California Department of Health Services (now the California Department of Public Health).
2003	Recycled Water Task Force	California Department of Water Resources	The Recycled Water Task Force presented its findings and recommendations in a final report titled *Water Recycling 2030: Recommendations of California's Recycled Water Task Force*. The task force estimated the future potential and costs of water recycling and made a wide variety of findings, many of which are reflected in this chapter. The task force issued 26 recommendations to increase water recycling. The recommendations are broad, are not limited to legislative actions or statutory changes, and as of this update are still worthy recommendations in need of being fully implemented. Work has been accomplished on many of the recommendations.
2003	Assembly Bill 334, Water Softening and Conditioning Appliances	California Assembly	This bill authorized local agencies to adopt regulations governing water softeners or conditioning appliances that discharge salt into the community sewer system. The Water Softening and Conditioning Appliances bill specifically authorizes local agencies, by ordinance, to limit the availability or use, or prohibit the installation, of water softening or conditioning appliances that discharge to the community sewer system.
2004	*Incidental Runoff of Recycled Water* memorandum	State Water Resources Control Board	This memorandum reviewed the legal requirements of federal and State statutes and regulations that relate to the regulation of incidental runoff and, to determine the available regulatory and enforcement options, conducted legal analysis and conducted stakeholder meeting to arrive at the decisions in the memorandum.
2006	Uniform Analytical Method for Economic Analysis framework	State Water Resources Control Board	This was a partially funded research project to develop a Uniform Analytical Method for Economic Analysis framework for evaluating the benefits and costs of water reuse by the WateReuse Foundation (August 2006). The State Water Resources Control Board convened the Economic Analysis Task Force with participation from State, federal and university members in fall 2008.

Year	Action	Organization	Summary
2006	Climate Action Team, created in response to Assembly Bill 32	California Environmental Protection Agency	The Climate Action Team was created to formulate measures to mitigate the effects of climate change. Water recycling can contribute to the reduction of greenhouse gas emissions by replacing energy-intensive imported water with local recycled water. To that end, the Climate Action Team formulated a water recycling measure to require the development and implementation of wastewater recycling plans. The water recycling CAT measure is identified in *Climate Change Scoping Plan: A Framework for Change* prepared by the California Air Resources Board in 2008.
2007	Assembly Bill 1481, Landscape Irrigation	California Assembly	This bill required the regional water quality control boards to prescribe general waste discharge requirements (a general permit) for landscape irrigation that uses recycled water for which the California Department of Public Health has established uniform statewide recycling criteria. The State Water Resources Control Board adopted the General Permit for Landscape Irrigation of Municipal Recycled Water, which further supports the use of recycled water in California while protecting the water quality.
2009	Recycled Water Policy	State Water Resources Control Board	This action was for implementing state statutes, regulations, and policies for recycled water projects to establish more uniform interpretation (State Water Resources Control Board 2009a, 2009b). This policy aims to increase the use of recycled water from municipal wastewater sources (as defined in California Water Code Section 13050(n)), in a manner that implements State and federal water quality laws.
2009	California Plumbing Code	California Department of Water Resources	This action addressed plumbing within buildings with both potable and recycled water systems. The California version of these provisions was adopted in 2009 and became effective in 2010. This section of the plumbing code will provide guidance throughout the state to safely plumb buildings for indoor use of recycled water for toilet and urinal flushing.
2009	Recycled water symbol change in code	California Department of Housing and Community Development	The department adopted a recycled water symbol change to remove the requirement for the skull-and-crossbones symbol in sections 601.2.2 and 601.2.3 of the California Plumbing Code. Now the symbol is a picture of a glass containing liquid, encircled, and with a line slashed through, indicating the liquid should not be ingested.

Figure 12-1 Municipal Recycled Water Affiliations with Other Resource Management Strategies

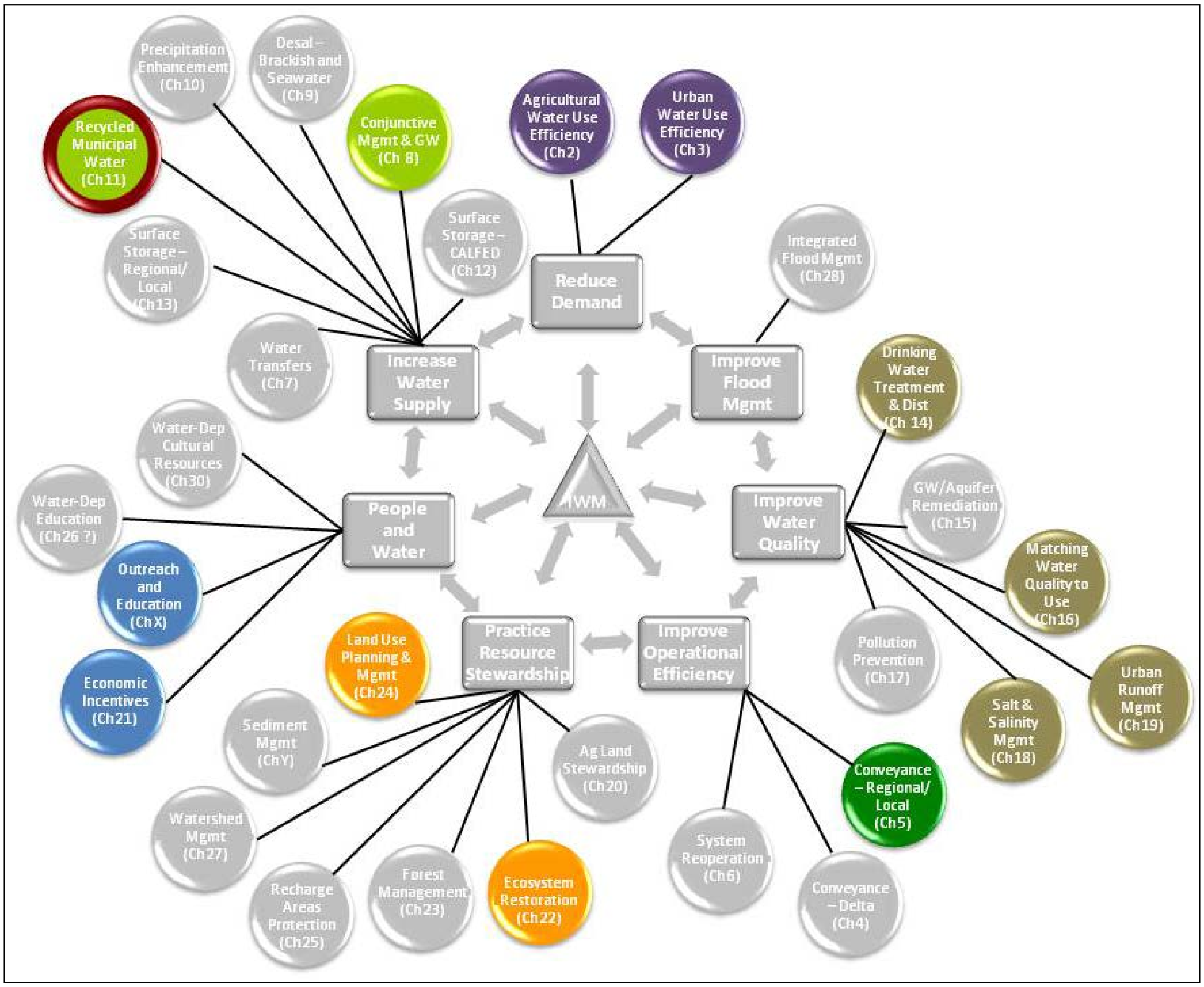


Figure 12-2 Municipal Recycled Water Cycle

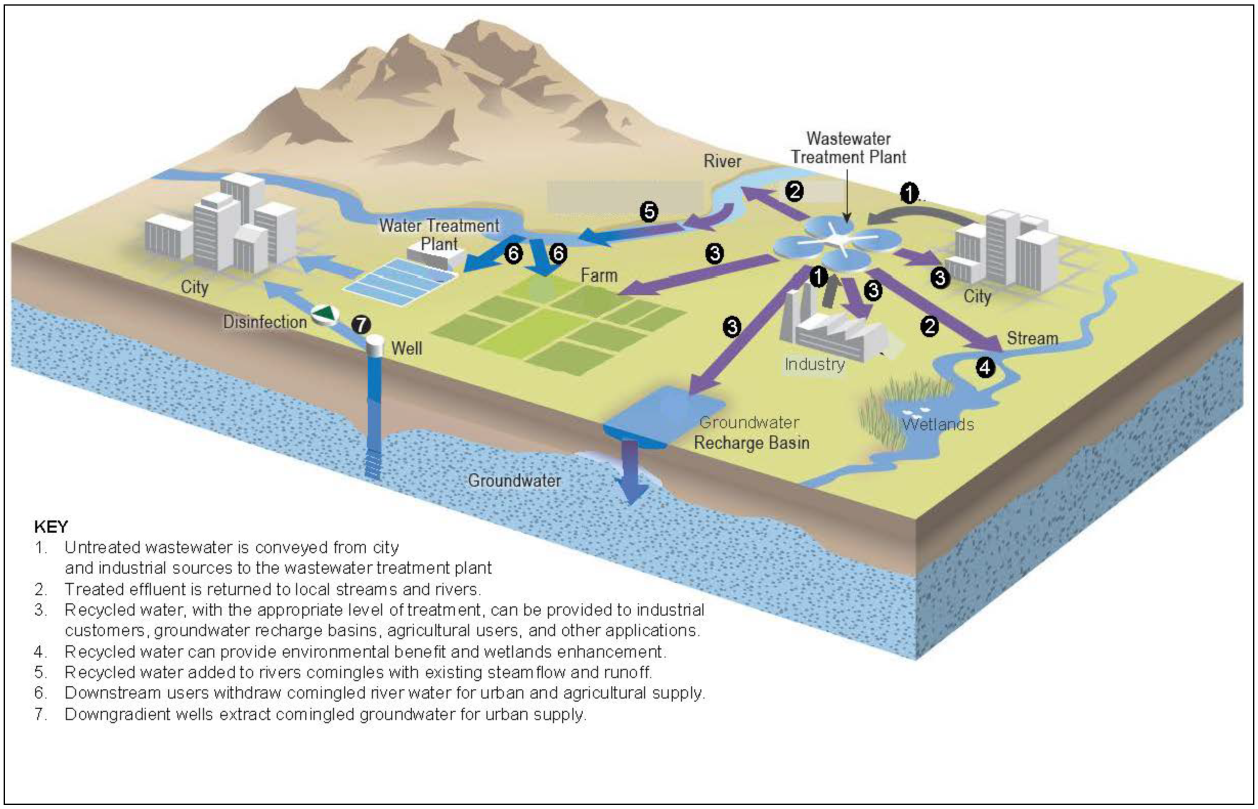


Figure 12-3 Potable and Non-Potable Municipal Recycled Water

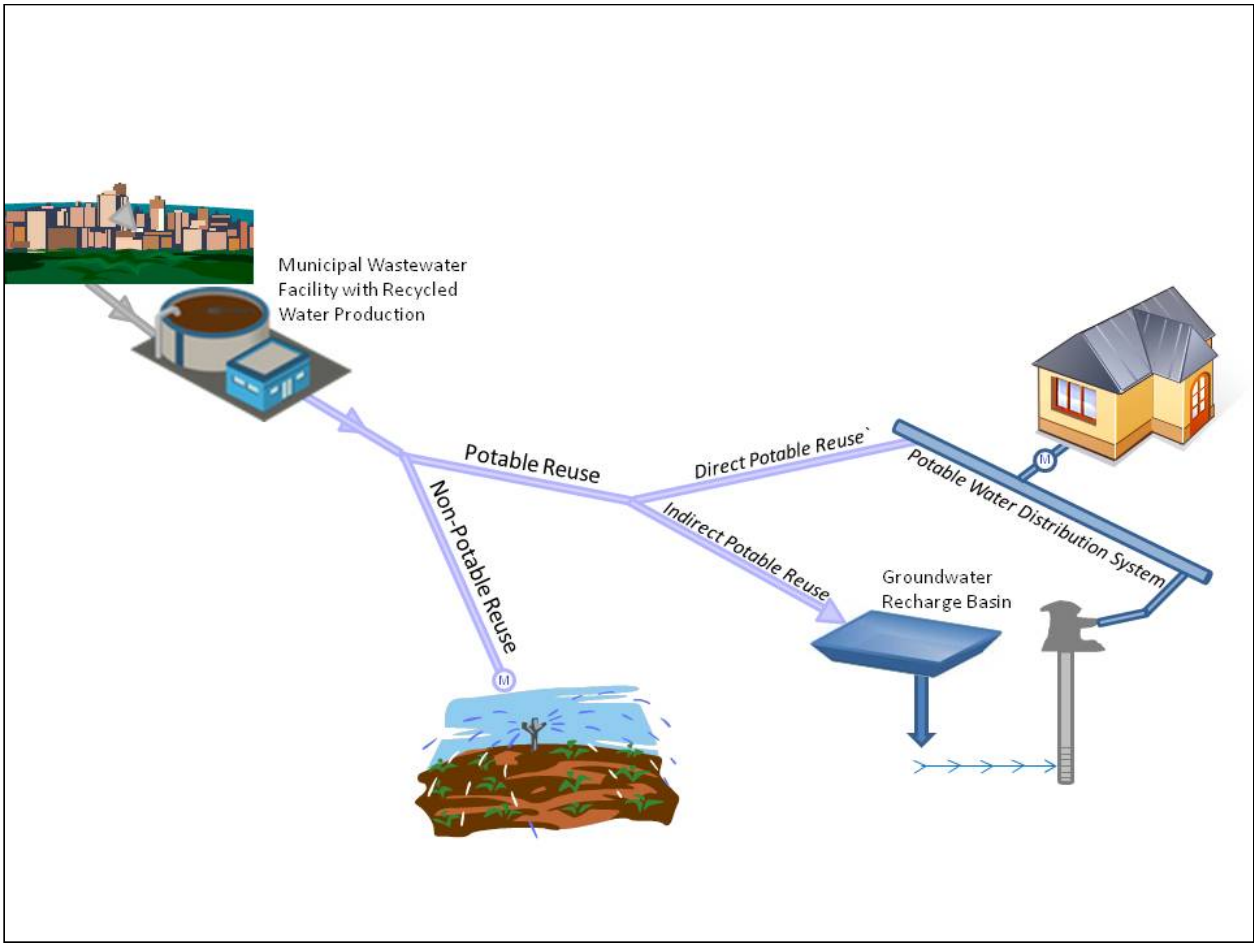


Figure 12-4 Municipal Recycled Water Use in California Since 1970

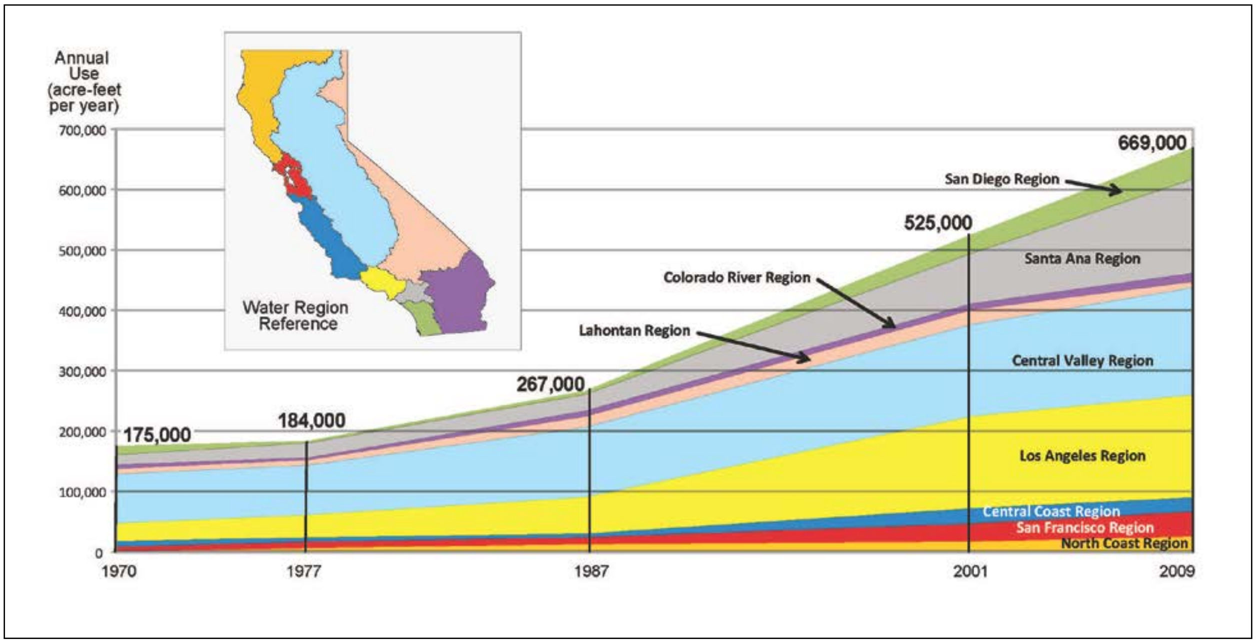


Figure 12-5 Changes in California's Recycled Water Beneficial Uses

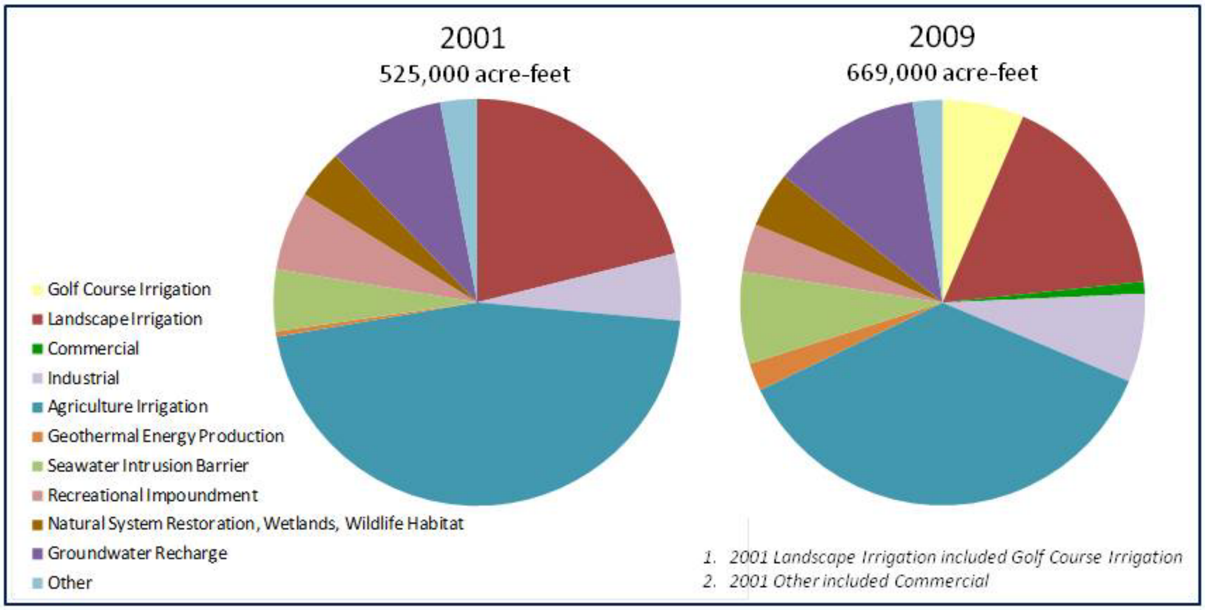


Figure 12-6 Municipal Recycled Water Use by County in 2009

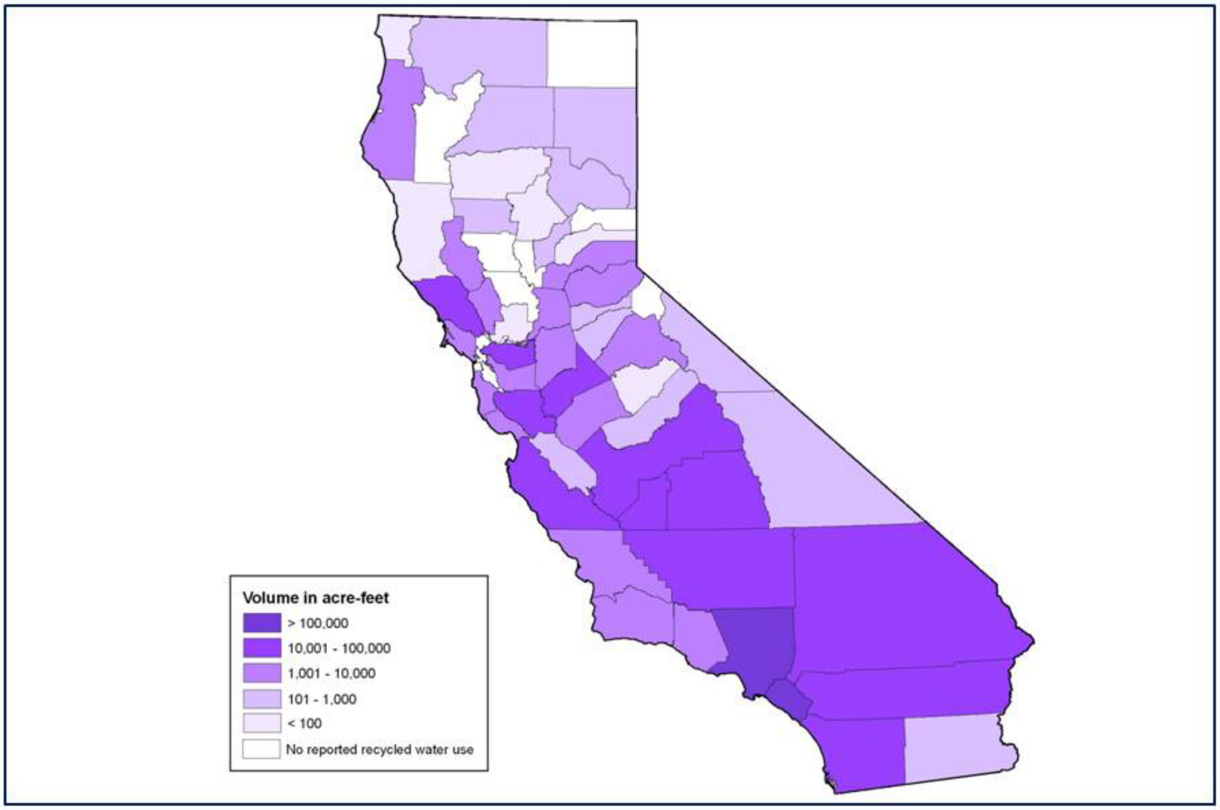
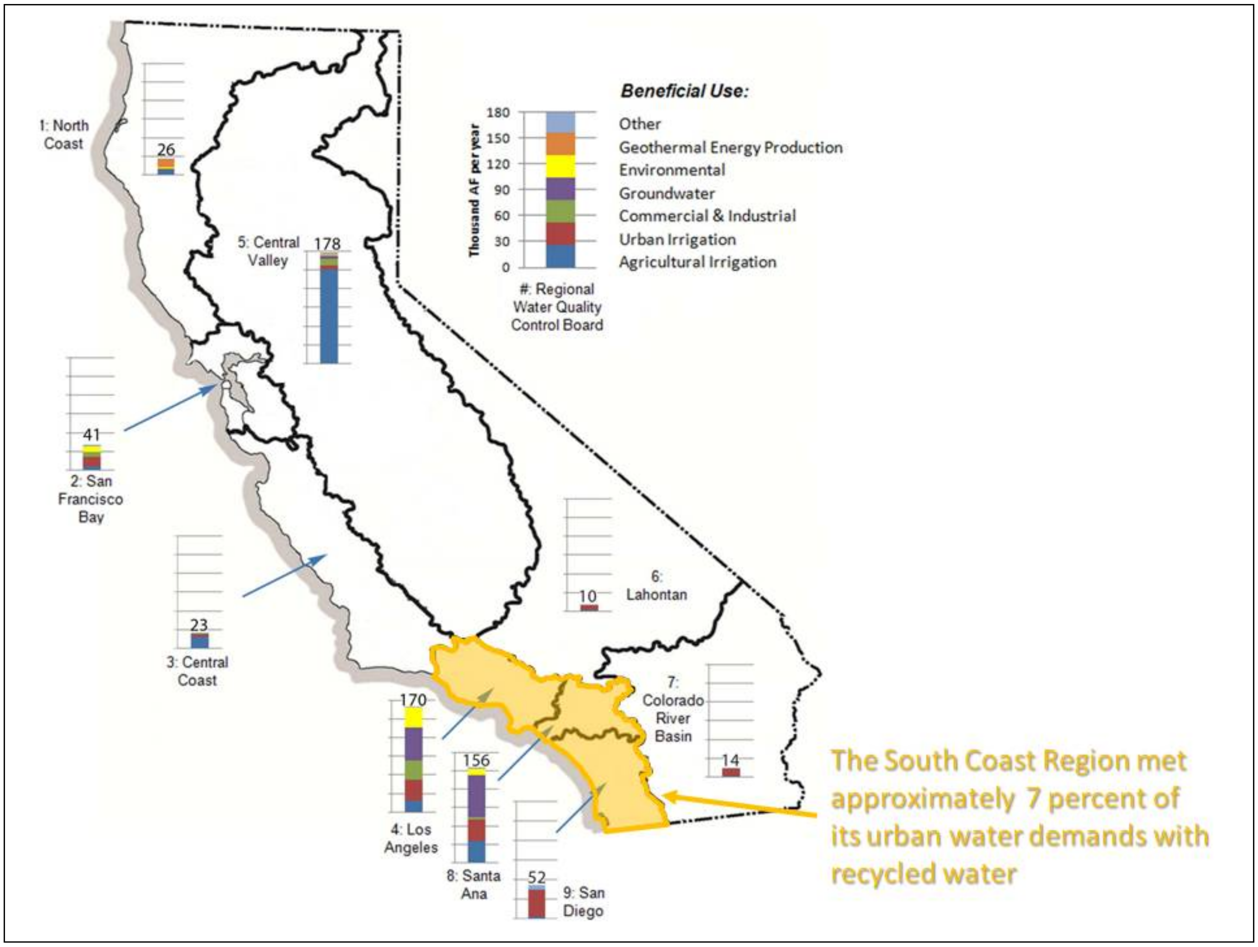


Figure 12-7 Regional Variations in Beneficial Uses of Municipal Recycled Water in 2009



Chapter 14. Surface Storage — Regional/Local — Table of Contents

Chapter 14. Surface Storage — Regional/Local

Surface storage is the term for the use of human-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role in California where the quantity, timing, and location of water demand frequently does not match the natural water supply availability. Many California water agencies rely on surface storage as a part of their water distribution systems. Reservoirs also play an important role in flood control and hydropower generation throughout California.

In addition, surface storage is often necessary for, or can increase the benefits from, other water management strategies, such as water transfers, conjunctive water management, and conveyance improvements. Some reservoirs contribute to water deliveries across several regions of the state while others provide only relatively local water deliveries. There are two general categories of surface storage reservoirs: (1) those formed by damming an active, natural river; and (2) those called offstream reservoirs, which require a human-made diversion or pumping of water from a river into storage.

Additional surface storage benefits can be developed by enlarging a dam and releasing the water it stores behind it, reoperating the releases from a dam (see Chapter 7 of this volume, “System Reoperation”), or modifying existing reservoirs. Smaller reservoirs typically store water only annually in the winter for supply use in summer, while larger reservoirs hold extra water over several years (known as carryover storage) as a reserve for droughts or other emergency supplies. In recent decades, reservoir operations have been most affected by the need to meet environmental regulations for the protection of affected fish species. Today, multiple-purpose surface storage projects balancing water supply, flood protection, hydropower production, water quality, and ecosystem needs are the norm.

The information in this chapter focuses on regional and local surface storage alternatives but does not include the major surface storage investigations of the State and federal CALFED Bay-Delta Program (CALFED), which are described separately in Chapter 13, “Surface Storage — CALFED.”

Surface Storage in California

California has nearly 200 surface storage reservoirs greater than 10,000 acre-feet (af) with a combined storage capacity of more than 41 million af. These were tabulated in chronological order within Volume 4 of *California Water Plan Update 2009*, “Reference Guide,” under the topic “Infrastructure” (California Department of Water Resources 2009). In addition, there are many more reservoirs smaller than 10,000 af that are used to provide for a wide range of water uses, such as stabilizing water delivery to customers or providing a backup supply for emergency needs.

Most of California’s reservoirs were constructed more than 40 years ago; the number of new reservoirs built has steadily declined since the 1960s. Only six new water supply reservoirs were constructed in California in the 1980s and 1990s, and only three have been completed since 2000. Examples of recently completed surface storage projects servicing local or regional areas include:

- The U.S. Bureau of Reclamation’s Warren H. Brock Storage Reservoir, located on the north side of the All-American Canal in Imperial County and completed in 2010.

- San Diego County Water Authority's Olivenhain Reservoir, completed in 2003.
- Metropolitan Water District of Southern California's Diamond Valley Reservoir, completed in 2000.
- The U.S. Army Corps of Engineers' and Orange County Flood Control District's Seven Oaks Reservoir, completed in 1999.
- Contra Costa Water District's Los Vaqueros Reservoir, completed in 1998.

The primary benefits of these new reservoirs include water supply reliability against catastrophic events and droughts, operational flexibility to meet peak summer water demands, water quality improvement, flood control, hydropower, and capturing excess flows.

A few enlargements of existing surface storage reservoirs have been completed since 2000 to meet anticipated future needs. Examples include the 60,000 af expansion of Los Vaqueros Reservoir by Contra Costa Water District completed in 2012; the 24,000 af expansion of Topaz Lake Reservoir on the California-Nevada border in 2008 to increase flood control; the 152,000 af enlargement of San Vicente Reservoir in San Diego County in 2006; and the 42,000 af expansion of Lake Kaweah reservoir in 2004 for flood protection and agricultural water supply.

Some surface storage has decreased across the state due to the removal of smaller, older, obsolete dams, primarily for the purpose of improving fish habitat and passage upstream. The California Department of Water Resources' (DWR's) Fish Passage Improvement Program, within the FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO), maintains a list of dams removed for fish passage purposes. DWR's June 2005 Bulletin 250, *Fish Passage Improvement: An Element of CALFED's Ecosystem Restoration Program*, describes structures removed to improve fish passage in California. One of the reasons that removal of existing dams is feasible is that newer, more efficient alternatives now serve the projects' original purposes for water deliveries or hydropower generation. In early 2010, a package of agreements was signed by many local stakeholder groups, three tribes, PacifiCorp (an electric power company), California, Oregon, and the federal government. This is leading to the removal of four hydroelectric dams on the Klamath River in Oregon and California. The removal will improve fish passage and possibly bring about a major fisheries restoration.

Throughout the past three decades, new regulations and legislation have required many reservoirs to be operated in a more environmentally friendly manner to improve downstream riverine habitats and fisheries. Specifically, many existing reservoirs have been reoperated to achieve ecosystem and river recreation benefits beyond the original project objectives.

As the competing water demands for agricultural, urban, and environmental needs have increased, the operational flexibility of California's various surface water systems has decreased. Today's water system managers face a complex array of competing demands on the use of limited reservoir storage, which potentially results in more water reductions during droughts.

The relative need for additional local surface storage development may be greatest in California's interior mountainous areas, such as the Cascades and the Sierra Nevada. Although much of the water used throughout the state originates in the mountains, these locations generally possess limited groundwater supplies, are particularly vulnerable to the impacts of climate change on hydrology, and have a shorter list of water management strategies available to meet local needs. This is largely due to geographic, hydrogeologic, or hydrologic limitations. Of these few strategies, new surface storage or enlargement of existing reservoir storage may hold the greatest potential for achieving local supply reliability objectives. Local surface storage development options also could include the reoperation of existing reservoirs through the development of water sharing or purchasing agreements with the downstream owners of existing reservoirs.

Potential Benefits

Many of California's reservoirs were originally built for one or two primary purposes, such as agricultural and municipal consumptive water use, flood control, or hydropower. However, over time the number of benefits asked of surface storage has generally expanded to include the following:

- Water quality management.
- Ecosystem management.
- Sediment transport management.
- River and lake recreation.
- Emergency water supply.
- System operational flexibility.

The presence of new surface storage allows water managers the flexibility to implement water management strategies more easily and more efficiently or to implement strategies simply not available without storage. Storage helps solve the temporal problem that occurs when the availability of water and the demand for water do not occur at the same time. Often regional conservation efforts are ineffective if any water conserved cannot be stored for later use. Storage allows water transfers between regions to occur at any time, not just when the water is needed for immediate use. In addition, water transfers early in the water year are generally less expensive, because of less demand, than transfers later in the water year. Surface storage is needed to enable and improve the effectiveness of conjunctive water management strategies by controlling the timing and volume of water ultimately conveyed for storage in groundwater basins.

Dealing with climate change impacts is a key concern for California's water purveyors. Climate change projections foresee more extreme weather, such as floods and droughts. More importantly, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall and creating larger and earlier runoff events. In addition, several million acre-feet of natural snowpack storage could be lost. By expanding surface storage capacity, water supply systems would have greater flexibility to capture the increased winter runoff and help control larger anticipated flood flows. Additional reserve storage would also allow water to be held over for all uses in dry years and droughts.

Potential Costs

Cost estimates for potential surface storage alternatives are not specified in this narrative because they vary extensively by region and specific project design. In most cases, the costs of multipurpose storage projects are shared by many beneficiaries and often include a State or federal cost-share component. The magnitude of individual project benefits and corresponding costs for new water supply, hydropower, flood management, and water quality, as examples, can be expected to vary significantly from project to project such that average cost information is not accurate.

Major Implementation Issues

Climate Change

Climate change projections indicate that California will experience more extreme weather, such as floods and droughts. At the same time, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall. This will lead to larger and earlier runoff events. As a result of these changes, several million acre-feet (af) of natural snowpack storage could be lost annually, reducing available water supply. In addition, the increasing severity of storms and increased runoff could overwhelm existing reservoir flood protection capacity and increase flood risks downstream.

Adaptation

Expansion of surface storage capacity can be an effective climate change adaptation strategy because increasing local and regional surface storage can provide greater flexibility for capturing runoff and managing supplies to meet increasingly variable future conditions. The ability to store water from wet years for use in dry years is critical to addressing increasing climate variability. Additional surface storage allows water to be held over from year to year as a hedge against dry years and droughts. Surface storage facilities south of the Sacramento-San Joaquin River Delta (Delta) allow water to be moved through the Delta when conditions allow it. Even if the water isn't needed immediately, the water can be stored for later use, providing additional protection from Delta supply interruptions and cutbacks. Surface storage provides unique climate change adaptation characteristics that are difficult to achieve with other management strategies: the ability to quickly detain and retain flood flows to protect downstream assets, and the ability to quickly release large quantities of water when demands increase or to meet instream temperature requirements.

Mitigation

Increases in greenhouse gas (GHG) concentrations in Earth's atmosphere are thought to be the main cause of current climate warming. Human activities, such as the burning of fossil fuels and deforestation, have been identified as the origin of higher GHG concentrations. Construction of surface storage reservoirs typically requires substantial construction and heavy equipment activity, which can emit large quantities of GHGs. In addition, offstream surface storage projects often require water to be pumped into the reservoir for storage, requiring electricity to run pumps (most electricity generation emits GHGs). In this way, development of new or expanded surface storage projects can work against efforts to mitigate the effects of climate change through GHG emission reduction efforts.

Conversely, depending on how individual surface storage projects are operated, they can provide substantial climate change mitigation benefits that in some cases more than offset emissions from construction. Surface storage reservoirs with hydroelectric generating capacity provide effective backup power supplies to be operated in tandem with intermittent renewable energy resources, such as wind and solar energy. Excess wind or solar energy can be used to run pumps to move water into offstream reservoirs, and water can be released from surface storage facilities to generate electricity when clouds obscure solar generation or when winds die down and reduce wind generation. Onstream reservoirs can produce substantial quantities of renewable, GHG-free hydroelectric energy.

Funding and Identifying Project Beneficiaries

Construction usually requires a substantial amount of money in a short time — millions to hundreds of millions of dollars. Included in the long-term capital outlay are planning costs, such as administrative, engineering, legal, financing, permitting, and mitigation costs. Some new-storage options, such as raising existing reservoirs, reoperating them, or constructing small local reservoirs, may require significantly less capital but may require local funding through revenue or general obligation bonds.

There are concerns related to how the beneficiaries will be determined, who will actually pay, and who will control a storage operation. One financing concept assumes that only the direct beneficiaries of a proposed storage project should pay for the construction and operation costs. However, many of the beneficiary groups do not have adequate financial resources to build large projects without outside financial assistance.

Another general financing concept relies on a large percentage of State and federal funding support to assist in the construction of new projects. With this method, the project beneficiaries would have a smaller, more affordable project cost component to fund. However, the process of obtaining funding approval from either federal or State government agencies generally requires substantially more time and justification documents. The challenge is to develop financial and operations agreements that have the best possibility for successful allocation of project costs corresponding directly to the beneficiaries and uses of a given project.

Impacts

New storage can affect environmental and human conditions and can create economic impacts for the surrounding community and flow impacts both upstream and downstream of diversions. New reservoirs may result in the loss of property tax revenue to local governments in the area where they are located, due to inundated developed land or land suitable for development, or may result in an increase of local property values by firming up a water supply. Regulatory and permitting requirements mean that surface storage investigations must consider potential impacts on streamflow regimes, potential adverse effects on designated wild and scenic rivers, potential water quality issues, potential changes in stream geomorphology, loss of fish and wildlife habitat, and risk of failure during seismic or operational events. Existing environmental laws require that these effects be addressed and potentially mitigated. Mitigation of environmental effects is normally accomplished through implementation strategies that avoid, minimize, rectify, reduce over time, or compensate for negative impacts. New surface storage projects are required to address impacts under the application of various laws, regulatory processes, and statutes, such as public trust doctrine, State dam safety standards, area-of-origin statutes, the California Environmental Quality Act, the National Environmental Policy Act, the Clean Water Act, and the California Endangered Species Act and federal Endangered Species Act.

Suitable Sites

Most of the best natural reservoir sites in California have already been developed, and environmental regulations and mitigation requirements impose significant constraints on development of new surface storage in California's mountainous areas. In some areas, the development of new offstream storage is a feasible alternative if the geographic terrain provides suitable locations. Another option that has received consideration in recent years is the rehabilitation and enlargement of existing reservoirs. This has the advantage of using an established reservoir site, but the feasibility and costs for rehabilitation of an older facility must be carefully evaluated.

Project Funding

The range of surface storage development options is generally more limited for smaller local agencies than for the State and federal governments, because limited agency funding and staff resources affect their capability to complete complex feasibility studies, design documents, environmental impact studies, and related project planning needs. These circumstances severely constrain the ability of local governments and agencies to finance and implement the projects necessary to sustain the local economy, preserve or restore riparian habitats, and provide water supplies for regional population growth. Traditionally, small local agencies have been unwilling to fund projects outside their service areas. However, recently, local partnerships through integrated regional water management plans (IRWMPs) have pooled resources and collaborated on local shared storage projects aimed at benefiting all regional participants.

Recommendations

1. Local agencies seeking to implement storage projects should develop a comprehensive methodology for analyzing all project benefits and costs. DWR should provide guidance, technical expertise, and planning process assistance to local agencies if requested.
2. Reservoir operators and stakeholders should continue to adaptively manage operations of existing facilities in response to increased understanding of system complexities and demands, as well as changes in natural and human considerations, such as social values, hydrology, and climate change.
3. DWR and other State, federal, and local resource management agencies should continue studies, research, and dialogue focused on a common set of tools that would help determine the full range of benefits and impacts, as well as the costs and complexities of surface storage projects.
4. Water resources scientists, engineers, and planners, including those at DWR, should recognize the potential long development time required for new surface storage in securing funding needed for continuity of planning, environmental studies, permitting, design, construction, and operation and maintenance.
5. Rehabilitation and possible enlargement of existing older dams and infrastructure should be given full consideration as an alternative to new reservoir storage.
6. As an alternative to new storage, agencies should consider the potential to develop water purchasing agreements to buy water from other agencies that own storage reservoirs with substantial water supplies.
7. Local agencies should investigate integrating existing surface storage with groundwater management or other water supply options (e.g., water use efficiency).
8. Local agencies should team with other regional agencies through the IRWMP process on new regional storage projects.
9. Surface storage can be the centerpiece of a comprehensive IRWMP offering multiple benefits and the flexibility to fully implement many other resource management strategies. Shared local or regional surface storage can enhance water user ability to implement conjunctive groundwater storage, integrate flood management practices, take full advantage of water transfers, assist in ecosystem restoration, and offer recreation benefits — all by augmenting consumptive water use.

Regional/Local Surface Storage in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

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Boxes

Chapter 20. Urban Stormwater Runoff Management

Urban stormwater runoff management is a broad series of activities to manage both stormwater and dry-weather runoff. Dry-weather runoff occurs when, for example, excess landscape irrigation water flows to the storm drain. Traditionally, urban stormwater runoff management was viewed as a response to flood control concerns resulting from the effects of urbanization. Concerns about the water quality impacts of urban runoff have led water agencies to look at watershed approaches to control runoff and provide other benefits (see Box 20-1, “Objectives of Urban Stormwater Runoff Management”). As a result, urban stormwater runoff management is now linked to other resource management strategies, including pollution prevention (covered in Chapter 18 of this volume), land use planning and management (Chapter 24), watershed management (Chapter 27), urban water use efficiency (Chapter 3), municipal recycled water (Chapter 12), recharge area protection (Chapter 25), and conjunctive management and groundwater (Chapter 9).

PLACEHOLDER Box 20-1 Objectives of Urban Stormwater Runoff Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Urban Stormwater Runoff Management in California

The traditional approach to runoff management views urban runoff as a flood management problem in which water needs to be conveyed as quickly as possible from urban areas to waterways in order to protect public safety and property. Consequently, precipitation-induced runoff in urban areas has been viewed as waste, and not a resource.

Urbanization alters flow pathways, water storage, pollutant levels, rates of evaporation, groundwater recharge, surface runoff, the timing and extent of flooding, the sediment yield of rivers, and the suitability and viability of aquatic habitats. The traditional approach to managing urban and stormwater runoff has generally been successful at preventing flood damage, but it has several disadvantages. In order to convey water quickly, natural waterways are often straightened and lined with concrete, resulting in a loss of habitat and impacts on natural stream physical and biological processes. Urbanization creates impervious surfaces, meaning stormwater does not infiltrate into subsurface aquifers. These impervious surfaces collect pollutants that are washed off to surface waters when it rains. The impervious surfaces also increase runoff volumes and velocities, resulting in streambank erosion, and potential flooding problems downstream. Because of the emphasis on removing the water quickly, the opportunity to use storm-generated runoff for multiple benefits is reduced.

A watershed approach for urban stormwater runoff management tries to emulate and preserve the natural hydrologic cycle that is altered by urbanization. The watershed approach consists of a series of best management practices (BMPs) designed to reduce the pollutant loading and reduce the volumes and velocities of urban runoff discharged to surface waters. These BMPs may include facilities to capture, treat, and recharge groundwater with urban runoff; public education campaigns to inform the public about stormwater pollution, including the proper use and disposal of household chemicals; and technical assistance and stormwater pollution prevention training.

Methods for recharging groundwater with urban runoff include having roof runoff drain to vegetated areas; draining runoff from parking lots, driveways, and walkways into landscaped areas with permeable soils; using dry wells and permeable surfaces; and collecting and routing stormwater runoff to basins. Infiltration may require the use of source control and pretreatment before infiltration. Infiltration enables the soil to naturally filter many of the pollutants found in runoff and reduces the volume and pollutant load of the runoff that is discharged to surface waters. An example is the Elmer Avenue Neighborhood Retrofit Demonstration Project (see Box 20-2). The watershed approach will not prevent, nor should it prevent, all urban runoff from entering waterways. Elements of the traditional conveyance and storage strategy are still needed in order to protect downstream beneficial uses, protect water right holders, and protect the public from floods. In addition to infiltration of stormwater, other BMPs include the use of rain barrels and cisterns to “harvest” stormwater for later use (e.g., irrigation), and the use of structural controls that are designed to capture stormwater runoff and slowly release it into streams in order to mimic the natural hydrograph that existed before development occurred. In Los Angeles, the nonprofit TreePeople organization constructed a 216,000-gallon cistern in Coldwater Canyon Park to collect and store stormwater from building rooftops and parking lots for irrigation use during the dry months (see Box 20-3).

PLACEHOLDER Box 20-2 Elmer Avenue Neighborhood Retrofit Demonstration Project

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

PLACEHOLDER Box 20-3 Stormwater Cistern, Coldwater Canyon Park, Los Angeles

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Urban stormwater runoff management has become more important and more controversial over the last two decades as municipal governments have been held increasingly responsible for pollutants washed from developed and developing areas within their jurisdictions into the storm sewer system and discharged into waterways. Unlike pollution from industrial and sewage treatment plants, pollutants in urban runoff and stormwater runoff come from many diffuse sources (see Box 20-4) and typically are not treated prior to being discharged to surface waters. As rainfall or snowmelt moves over the urban landscape, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and, potentially, groundwater. Pollution associated with discharges from a storm sewer system can occur outside of storms also, from landscape irrigation flows, improper disposal of trash or yard waste, illegal dumping, and leaky septic systems.

PLACEHOLDER Box 20-4 Examples of Pollution in the Urban Environment

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Runoff in the urban environment, both storm-generated and dry weather flows, has been shown to be a significant source of pollutants to the surface waters of the nation. As a result, the 1987 amendments to the federal Clean Water Act (CWA) required that discharges from municipal separate storm sewer systems serving a population of 100,000 or more must be in compliance with requirements contained in National Pollutant Discharge Elimination System (NPDES) permits. The U.S. Environmental Protection Agency (EPA) promulgated regulations for these discharges in 1990. These regulations were subsequently amended in 1999 to require that municipal separate storm sewer systems that served populations fewer than 100,000 and were located in an urbanized area were subject to requirements contained in an NPDES permit. In California, the authority to regulate urban and stormwater runoff under the NPDES system has been delegated by EPA to the State Water Resources Control Board (SWRCB) and the nine regional water quality control boards (RWQCBs).

Under the initial NPDES permits issued in the 1990s, municipalities were required to develop and implement a plan to reduce the discharge of pollutants into waterways, including the discharges from areas of new development and significant redevelopment. For the new development and redevelopment projects, the permit requirements were generally met by implementing BMPs that addressed discharges taking place during the construction activity but did not address discharges occurring after construction was completed (post-construction controls). Since the first municipal stormwater permits were adopted, and with continued beach closures and other pollution problems associated with urban runoff, it has become clear that post-construction controls, retrofit, and more advanced measures will be required in some areas to comply with water quality regulations (see Box 20-5).

PLACEHOLDER Box 20-5 Implementation Plan for Urban Stormwater Runoff Management Programs

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

The SWRCB and RWQCBs seek opportunities for managing urban runoff that will result in multiple benefits. Low-impact development (LID) is one such collection of management techniques that has multiple benefits. LID is a sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional stormwater management, which collects and conveys stormwater runoff through storm drains, pipes, or other conveyances to a centralized stormwater facility, LID takes a different approach by using site design and stormwater management to maintain the site's predevelopment runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall. LID has been a proven approach in other parts of the country and is seen in California as an alternative to conventional stormwater management. The SWRCB and RWQCBs are advancing LID in California in various ways.

LID can be used to benefit water quality, address the modifications to the hydrologic cycle, and be a means to augment local water supply through either infiltration or water harvesting. In light of this, the SWRCB and RWQCBs are incorporating the principals of LID into the permits now being issued and are funding projects that highlight LID using the various voter-approved bond funds.

The SWRCB and RWQCBs are also required under the federal CWA Section 303(d) and federal regulations (Code of Federal Regulations [CFR] Title 40, Section 130) to prepare a list of water bodies requiring total maximum daily loads (TMDLs) because they do not meet water quality standards and set priorities for these water bodies. The Section 303(d) list was last revised in 2010 and is currently being updated for 2012. Federal regulations require the Section 303(d) list to be updated every two years. TMDLs represent the total pollutant load a water body can assimilate before the water body's beneficial uses are considered to be impaired and water quality standards are no longer met. Through the process of establishing the Section 303(d) list of impaired water bodies, it has often been found that urban runoff is a source of pollutants contributing to the impairment.

NPDES permits now issued to local agencies for discharges of stormwater require the implementation of specific measures to reduce the amount of pollutants in urban runoff. Permits for discharge to listed water bodies having a TMDL must be consistent with the waste load allocations in a TMDL. Under California law, TMDLs include implementation plans for meeting water quality standards. The implementation plans allow for time to implement control strategies to meet water quality standards.

Potential Benefits

The primary benefits of urban stormwater runoff management are to reduce surface water pollution and improve flood protection. Additional benefits may be to increase water supply through groundwater recharge in areas with suitable soil and geological conditions, and where pollution prevention programs are in place to minimize the impact on groundwater. Groundwater recharge and stormwater retention sites can also be designed to provide additional benefits to wildlife habitat, parks, and open space.

Underground facilities can store runoff and release it gradually to recharge a groundwater aquifer or release it to surface waters in a manner that mimics the natural hydrologic cycle. Captured stormwater can also be used as a source of irrigation water rather than using potable water. For instance, a school campus can solve its flooding problem and develop a new sports field at the same time. These may provide secondary benefits to the local economy by creating more desirable communities. By keeping runoff on a site, storm drain systems can be downsized, which could reduce the installation and maintenance costs of such systems. A watershed planning approach to managing urban runoff allows communities to pool economic resources and obtain broader benefits to water supply, flood control, water quality, open space, and the environment.

Statewide information on the benefits of increased management of urban runoff is not available, but examples from local efforts exist. The Fresno-Clovis metropolitan area has built an extensive network of stormwater retention basins that not only recharges more than 70 percent of the annual stormwater runoff (17,000 acre-feet [af]) and removes most conventional stormwater pollutants, but also recharges excess Sierra Nevada snowmelt during the late spring and summer (27,000 af). Los Angeles County recharges an average 210,000 af of storm runoff a year, which reduces the need for expensive imported water. Agencies in the Santa Ana watershed recharge about 78,000 af of local storm runoff a year. The Los Angeles and San Gabriel Watershed Council has estimated that if 80 percent of the rainfall that falls on just a quarter of the urban area within the watershed (15 percent of the total watershed) were captured and reused, total runoff would be reduced by about 30 percent. That translates into a new supply of 132,000 af of water per year or enough to supply 800,000 people for a year.

The City of Santa Monica is an example of a municipality that is taking a watershed approach to managing urban runoff. Santa Monica’s primary goal is to treat and reuse all dry-weather flows. This turns a perceived waste product into a local water resource so that beach water quality is protected and the local nonpotable water supply is augmented. However, if dry-weather discharges are necessary, the city’s secondary goal is to release only treated runoff into waterways. Both goals improve water quality of the

Santa Monica Bay. The city's goals promote development such that urbanization works with nature and the hydrologic cycle.

At the "lot" or home-owner level, LID techniques and practices can be used to reduce the amount of runoff being generated and slow its release to the storm sewer system or surface waters. Captured runoff can be harvested and stored for later use on-site. LID techniques and practices include rain barrels, cisterns, rain gardens, swales, trench drains, land grading, permeable pavers, tree-box filters, and green roofs. For further information, see Volume 3, Chapter 24, "Land Use Planning and Management." An analysis aimed at quantifying the benefits of LID techniques was conducted by the Natural Resources Defense Council and University of California, Santa Barbara (2009), and is summarized in Box 20-6; the full report is included in Volume 4.

PLACEHOLDER Box 20-6 Efforts to Quantify Benefits of Low-Impact Development

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Increase Local Water Supplies through Stormwater Capture

[NOTE: Plan to include subsection in future draft that discusses increasing water supplies through stormwater capture and use.].

Potential Costs

Information about statewide costs to implement urban stormwater runoff management activities is not available. The SWRCB contracted with the Office of Water Programs at California State University, Sacramento, to survey six communities to estimate the costs of complying with their NPDES stormwater permits (California State University, Sacramento, 2005). Although this may address the cost for a municipality to comply with specific programmatic elements of an NPDES permit, it may not be the most applicable for looking at watershed programs seeking multiple benefits.

The City of Santa Monica illustrates the costs of managing urban runoff from the perspective of treating dry-weather flows. The city has a stormwater utility fee that generates about $1.2 million annually and has been in place since 1995. The funds are used for various programs to reduce or treat runoff. They go to the city's urban runoff management coordinator for the maintenance of the storm drain system and to help support other city staff that conduct runoff work. Additional funds are spent by other divisions to perform runoff management efforts, such as street sweeping, some trash collection, sidewalk cleaning, and purchasing and maintaining equipment. The city has also received five grants totaling more than $3.5 million for the installation of structural BMP systems, all of which will require long-term maintenance and monitoring by the city. The culmination of the city's program is the $12 million Santa Monica Urban Runoff Recycling Facility (SMURRF), a joint project of the City of Santa Monica and the City of Los Angeles. The SMURRF project is a state-of-the-art facility that treats dry-weather runoff water before it reaches Santa Monica Bay. Up to 500,000 gallons per day of urban runoff generated in parts of the cities of Santa Monica and Los Angeles can be treated by conventional and advanced treatment systems at the SMURRF.

Major Implementation Issues

Lack of Integration with Other Resource Management Strategies

Land use planning is not conducted on a watershed basis. Many agencies spend millions of dollars annually addressing urban runoff problems with very little interagency coordination (both within the municipality and with other neighboring municipalities) even though downstream communities can be affected by activities upstream. In other words, internal communications within local government can be improved to ensure that the program goals and direction of one branch do not conflict with those of another; and local governments need to communicate with one another to ensure that land use planning on a regional level is complementary across jurisdictional boundaries.

Solutions to managing urban runoff are closely tied to many interrelated resource management strategies, including land use planning, watershed planning, water use efficiency, recycled water, protecting recharge areas, and conjunctive management. How and why water is used in the urban environment needs to be considered comprehensively within a watershed.

Climate Change

Climate change models project more frequent flood-producing storm events. These storms may overwhelm existing urban stormwater infrastructure, resulting in more localized flooding. During drought periods, additional landscape irrigation could create higher levels of runoff. In addition, contaminant buildup during extended dry conditions could result in increased impacts on coastal areas when large storms flush those contaminants out to coastal water bodies or the ocean.

Adaptation

Urban planning and development that incorporates opportunities to capture and infiltrate rainwater will assist cities in adapting to higher-precipitation storm events. Landscape design elements such as xeriscaping, drought-tolerant gardens, and bioswales can improve water capture and infiltration. Minimizing impervious areas, using regionally appropriate landscaping features, and seeking opportunities for harvesting rainwater for on-site use or infiltrating rainfall into ground water aquifers in new development will help protect against flooding from stronger storms.

Mitigation

Harvesting rainwater at the site level and infiltrating it on a regional scale can result in reducing localized flooding, as well as increasing local water supply through groundwater recharge. Harvesting when combined with the use of regionally appropriate landscaping can also reduce the amount of water needed to be delivered to the home for landscape irrigation. These activities can reduce the demand for energy-intensive water supplies, thus reducing the amount of greenhouse gas emissions produced from urban water supply.

Lack of Funding

The two main aspects of implementing urban stormwater runoff management measures are source control, including education, and structural controls. In highly urbanized areas, major costs for structural controls include purchasing land for facilities and constructing, operating, and maintaining treatment facilities. Local municipalities have limited ability to pay for retrofitting existing developed areas within existing budgets. The provisions of Proposition 218 have limited local municipalities' ability to increase fees to pay for services required to implement robust urban stormwater runoff management programs. Additional information on Proposition 218 is available in Volume 4.

Effects of Urban Runoff on Groundwater Quality

The movement of pollutants in urban runoff is a concern. Urban runoff contains chemical constituents and pathogenic indicator organisms that could impair water quality. Studies by the EPA (U.S. Environmental Protection Agency 1983) and the U.S. Geological Survey (Schroeder 1993) indicate that all monitored pollutants stayed within the top 16 centimeters of the soil in the recharge basins. The actual threat to groundwater quality from recharging urban runoff depends on several factors, including soil type, source control, pretreatment, solubility of pollutants, maintenance of recharge basins, current and past land use, depth to groundwater, and the method of infiltration used.

Nuisance Problems/Other Concerns

The presence of standing water in recharge basins and other drainage and storage structures can lead to vector problems, such as mosquitoes and the transmission of West Nile virus. The California Department of Public Health has developed guidelines that address the issue of vector control in basins. These same concerns also apply to the on-site capture of runoff for later use.

A number of state agencies are encouraging infiltration and have found it to be an effective means of dealing with surface water pollution and the excess volumes and velocities of runoff created in the urban environment. However, it is also acknowledged that infiltration is not appropriate in all circumstances. Examples of this would be the widespread use of infiltration in a brownfield development or infiltrating large amounts of water in hillside developments where slope stability may be an issue.

Protecting Recharge Areas

Local land use plans often do not recognize and protect groundwater recharge and discharge areas. Areas with soil and geologic conditions that allow groundwater recharge should be protected where appropriate. If development does occur in these areas, the amount of impervious cover should be minimized, and infiltration of stormwater should be encouraged on both a regional scale as well as at the "lot" level. In 2010, the Los Angeles and San Gabriel Rivers Watershed Council (now known as the Council for Watershed Health) prepared a water augmentation study that looked at the results of stormwater infiltration and the impact on groundwater (Los Angeles and San Gabriel Rivers Watershed Council 2010). Refer to Volume 3, Chapter 25, "Recharge Area Protection," for additional information.

Misperceptions

There are many misperceptions about urban runoff and its management. Urbanization changes the native landscape and creates many sources of urban runoff pollution. Urbanization brings about increases in impervious surfaces that do not allow precipitation to infiltrate into the ground, causing increased runoff volume and velocity that changes streams to become more "flashy." In addition, the traditional way that the urban environment has been landscaped (lawns) has called for the use of lawn care products to keep lawns green and free from weeds and other unwanted vegetation. The use of lawn care products creates a pollutant source when excess watering washes products off and into the storm sewer system. Likewise, the transportation system creates sources of runoff pollution.

Storm sewer systems have been designed to carry water away from the urban environment in order to reduce localized flooding during storm events. The systems have worked well in this regard, which has led to the public often times viewing runoff as a waste. However, with increasing demands on a limited water supply (surface water and groundwater) and climate-induced changes in precipitation patterns, water that otherwise would run off and be discharged to surface waters is being viewed as a resource. Changes in how new developments are planned and built, and changes in how we manage the existing urbanized areas, can create opportunities to capture runoff for future use.

Existing Codes

There are current codes and ordinances within State and local government that could conflict with some of the goals of managing urban runoff. Dry-weather flows have been shown to be significant sources of pollution, with one of the primary dry-weather flows being runoff associated with landscape irrigation and lawn watering. Reduction/elimination of these flows not only provides a water quality benefit, but also reduces the amount of potable water that is being used in a community. However, some municipalities have “green lawn” ordinances, and compliance oftentimes leads to runoff. Other codes require minimum street widths that can inhibit the minimization of impervious surfaces.

Recommendations

State

State agencies should:

1. Coordinate their efforts to decide how urban stormwater runoff management should be integrated into their work plans.
2. Coordinate their efforts to develop a single message to the public and local government regarding managing urban runoff through the use of low-impact development (LID) techniques.
3. Coordinate their efforts to develop appropriate site design requirements that can be incorporated into either local building codes or statewide building standards.
4. Lead by example by incorporating LID into projects to showcase the use, utility, and cost of the features. Site design should be given the same attention that indoor environmental quality, energy usage, etc., are given in the design, funding, and construction of public projects.
5. Encourage public outreach and education about the benefits and concerns related to funding and implementation of urban runoff measures.
6. Provide leadership in the integration of water management activities by assisting, guiding, and modeling watershed and urban runoff projects.
7. Work with local government agencies to evaluate and develop ways to improve existing codes and ordinances that currently stand as barriers to implementing and funding urban stormwater runoff management.
8. Provide funding and develop legislation to: support development of urban runoff and watershed management plans; enable local agencies and organizations to pursue joint-venture, multipurpose projects; and collect information on regional urban stormwater runoff management efforts.
9. Assist agencies with developing recharge programs with appropriate measures to protect human health, the environment, and groundwater quality.
10. Work with federal policymakers and industry to create research and development incentives and to develop standards to reduce urban runoff from transportation-related sources, including lubricant systems, cooling systems, brake systems, tires, and coatings.

11. Maintain a publicly accessible clearinghouse of information regarding practices that can be used to address water quality issues associated with urban stormwater runoff management.
12. Work with local government to seek legislative solutions to the limitations imposed by Proposition 218.

Local Agencies and Governments

Local agencies and governments should:

13. Design recharge basins to minimize physical, chemical, or biological clogging; periodically excavate recharge basins when needed to maintain infiltration capacity; develop a groundwater management plan with objectives for protecting both the available quantity and quality of groundwater; and cooperate with vector control agencies to ensure the proper mosquito control mechanisms and maintenance practices are being followed.
14. Seek opportunities to include LID techniques in public works projects.
15. Work with the development community to identify opportunities to address urban stormwater runoff management, including LID, in development and redevelopment projects.
16. Develop urban stormwater runoff management plans, integrating the following practices into the development process:
    A. Understand how land use affects urban runoff.
    B. Communicate with other municipalities regarding how land use will change the hydrologic regime on a regional basis and how this change is being addressed.
    C. Look for opportunities to require features that conserve, clean up, and reduce urban runoff in new development and in more established areas when redevelopment is proposed.
    D. Be aware of technological advances in products and programs through communications with other municipalities, branches of local government, and professional organizations.
    E. Learn about urban runoff and watershed ordinances already in place. For example, the City of Santa Monica and the Fresno Metropolitan Flood Control District already have extensive urban stormwater runoff management programs in place.
    F. Integrate urban stormwater runoff management with other resource management strategies covered in this volume, including pollution prevention, land use planning and management, watershed management, urban water use efficiency, municipal recycled water, recharge area protection, and conjunctive management and coordinate both within and across municipal boundaries.
    G. Be sensitive to the fact there are going to be sites where it is not appropriate to infiltrate urban runoff and stormwater flows.
    H. Integrate urban stormwater runoff management with development goals and strategies in the community.
17. Communicate with citizens about pollution of urban runoff and what can be done about it.
18. Create lists of locally accepted practices that could be used at the homeowner level to address urban runoff.
19. Review codes and ordinances to determine whether there are impediments to managing urban runoff and amend these as needed or as is appropriate.
20. Coordinate urban stormwater runoff management with local water purveyors to ensure the goals and activities of each complement each other rather than conflict.
21. Seek opportunities to provide incentives for the installation of LID features at the lot level for new and existing developments.

Urban Stormwater Runoff Management in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports, and in the sustainability indicators. If the three mentions aren't consistent, the reason for the conflict will be discussed (e.g., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

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http://www.waterboards.ca.gov/water_issues/programs/nps/docs/5yrplan/nps5yrplan_20032008.pdf. Accessed: Oct. 29, 2012.

Box 20-1 Objectives of Urban Stormwater Runoff Management

- Protection and restoration of surface waters by minimizing pollutant loadings and negative impacts resulting from urbanization.
- Protection of environmental quality and social well-being.
- Protection of natural resources (e.g., wetlands and other important aquatic and terrestrial ecosystems).
- Minimization of soil erosion and sedimentation problems.
- Maintenance of predevelopment hydrologic conditions.
- Protection and augmentation of groundwater supplies.
- Control and management of runoff to reduce or prevent flooding.
- Management of aquatic and riparian resources for active and passive pollution control.

Box 20-2 Elmer Avenue Neighborhood Retrofit Demonstration Project

The Elmer Avenue Neighborhood Retrofit Demonstration Project is part of the Los Angeles Basin Water Augmentation Study, led by the Council for Watershed Health (formerly the Los Angeles and San Gabriel Rivers Watershed Council) and including multiple stakeholders. The project was designed to capture and infiltrate the runoff generated by a 0.75-inch design storm within the 40-acre residential catchment that fed surface flow to the 5800 block of Elmer Avenue. This block is a residential area with 24 single-family homes, located in the San Fernando Valley, that was susceptible to floods due to the absence of storm drains and sidewalks. The project improves drainage and groundwater recharge and provides stormwater quality mitigation through the application of multiple low-impact development strategies on both public and private lands (Los Angeles and San Gabriel Rivers Watershed Council 2010).

A wide range of integrated management strategies and practices are part of the demonstration, from individual rain barrels (cisterns) on single-family homes to wide-scale infiltration trenches that were constructed underground along roadways. All of the systems are a focus of an extensive monitoring program under way that provides knowledge about the physical and social effectiveness of the installed systems.

The project was designed to provide 16 acre-feet (af) of groundwater recharge annually. Measurements and estimates suggest that in 2010-2012 the systems infiltrated about 40 af over the two years, exceeding the groundwater recharge design goal. Two large infiltration systems are under the roadway and handle the bulk of the recharge. Bio-swales are used to capture flow from the residential parcels. The project included retrofits to individual homes, with features such as porous pavement, rain barrels, native planting, and rain gardens.

PLACEHOLDER Photo A Elmer Avenue Infiltration Galleries Before They Were Buried under the Street

[Any draft photos available for the public review draft appear after this box.]

PLACEHOLDER Photo B Depressed Swale Mini-Creek Bed Center, Complete with Drought-Resistant Native Landscaping (sidewalk left, curb right)

[Any draft photos available for the public review draft appear after this box.]

PLACEHOLDER Photo C Elmer Avenue Curbside Bio-Swale Filled by Half-Inch Rainstorm

[Any draft photos available for the public review draft appear after this box.]

Photo A Elmer Avenue Infiltration Galleries Before They Were Buried under the Street

[photo to come]

Photo B Depressed Swale Mini-Creek Bed Center, Complete with Drought-Resistant Native Landscaping (sidewalk left, curb right)

[photo to come]

Photo C Elmer Avenue Curbside Bio-Swale Filled by Half-Inch Rainstorm

[photo to come]

Box 20-3 Stormwater Cistern, Coldwater Canyon Park, Los Angeles

In an effort to reduce demand for imported water supplies and cost, the nonprofit organization TreePeople designed and constructed a 216,000-gallon cistern, underground stormwater storage tank, in Coldwater Canyon Park in Los Angeles. This innovative runoff management strategy captures and stores stormwater runoff to use on-site for irrigation during the dry months. The installation includes a stormwater storage and collection system to capture stormwater that falls on nearby building rooftops and a parking lot. Stormwater that falls onto the parking lot flows into a centralized gravel trench drain, which filters it. The water then seeps into pipes and is carried to the cistern. The buildings are also fitted with rain barrels in order to provide additional storage for rainwater. These barrels can be used to water urban watershed gardens that help allow for more infiltration of water on-site (TreePeople 2012b).

In 2010, the TreePeople facility captured more than 70,000 gallons from a three-day Los Angeles storm. A TreePeople Web page (TreePeople 2012a) states, "This solution prevents local flooding, helps keep beaches clean and if implemented widely, could stimulate the economy. … Last year, despite the declared drought emergency, TreePeople's cistern captured enough rainwater to meet most of Coldwater Canyon Park's irrigation needs, greatly minimizing the nonprofit's dependency on the L.A. City water grid."

PLACEHOLDER Photo A TreePeople's 216,000-Gallon Cistern Under Construction

[Any draft figures or photos that accompany this text for the public review draft will follow this box.]

PLACEHOLDER Photo B TreePeople's Parking Lot with Storm Drains Piped to Cistern

[Any draft figures or photos that accompany this text for the public review draft will follow this box.]

Photo A TreePeople's 216,000-Gallon Cistern Under Construction

[photo to come]

Photo B TreePeople's Parking Lot with Storm Drains Piped to Cistern

[photo to come]

Box 20-4 Examples of Pollution in the Urban Environment

- Herbicides and pesticides from landscaped areas (residential and commercial), golf courses, city parks, etc.
- Oil, grease, and heavy metals from normal vehicle use (automobiles, trucks, and buses) that accumulate on streets, roads, highways, driveways, and parking lots (leaks and drips, brake pad dust, tire wear, etc.).
- Sediment from improperly managed construction activities.
- Litter and green waste.
- Bacteria from improperly maintained septic systems, encampments, and waste from pets and wildlife.
- Nutrients from the application of excess fertilizers on landscaped areas (home, commercial, parks, etc.).
- Illegal dumping of material into the storm sewer system (used crankcase oil, antifreeze, pesticide container rinse water, etc.).
- Atmospheric deposition.
- Natural catastrophes.
- Building maintenance (pressure washing of lead-based paints, rinsing of walkways, etc.).
- Sanitary sewer overflows.
- Illegal cross connections with the sanitary sewer systems.

Box 20-5 Implementation Plan for Urban Stormwater Runoff Management Programs

Implementation of urban stormwater runoff management programs will require local agencies to:

- Promote coordination of interagency programs that protect water quality from urban runoff pollution.
- Reduce the potential for contamination of surface water and groundwater that results from uncontrolled or poorly controlled urban runoff practices.
- Develop tools to assess the effectiveness of urban water pollution programs.
- Increase the availability of regulatory and guidance documents and instructional workshops to demonstrate effective urban runoff pollution control programs and policies.
- Reduce the number of uncontrolled urban runoff pollution sources by increasing the number of municipalities, industries, and construction sites that use non-point source management measures and fit under the permitted State Storm Water Program.
- Develop and implement watershed-based plans, including total maximum daily loads and stormwater management programs in order to identify and address impacts from urban land use.

Box 20-6 Efforts to Quantify Benefits of Low-Impact Development

Low-impact development (LID) practices that emphasize infiltrating stormwater to recharge groundwater supplies or capturing rooftop runoff in rain barrels and cisterns for on-site use can be used to increase access to safe and reliable sources of water for end users, while reducing the amount of energy consumed and the greenhouse gas (GHG) emissions generated by supplying the water. Analysis by the Natural Resources Defense Council and University of California, Santa Barbara (2009) demonstrates that implementing LID practices at commercial and residential development and redevelopment, in urbanized Southern California and limited portions of the San Francisco Bay area, has the potential to increase water supplies by 229,000-405,000 acre-feet (af) per year by 2030. The water savings at these locations translate into electricity savings of 573,000-1,225,500 megawatt-hours (MWh), avoiding the release of 250,500-535,000 metric tons of carbon dioxide per year, as the increase in energy-efficient local water supply from LID results in a decrease in need to obtain water from energy-intensive imported sources of water, such as the State Water Project or energy-intensive processes such as ocean desalination.

The study analyzed geographic-information-system-based land use data, water supply patterns, and the energy consumption of water systems in California in order to estimate the water supply, energy use, and GHG emissions benefits of LID on a regional basis, under a conservative set of assumptions. The ranges presented for each benefit reflected a set of variables and input values used to create low and high estimates of potential savings. The study considered the percentage of impervious surface cover in the landscape; the density of development; the average annual rainfall; the soil type and infiltrative capacity; residential and commercial development rates; the energy intensity of current imported and local water supply sources; the effects of evapotranspiration; and local conditions, such as the presence of contamination or of shallow groundwater that may affect groundwater recharge.

Because the study included only a subset of urban areas within California, and incorporated only residential and commercial development, the true value of LID is likely higher than the results indicate. For example, expanding the use of LID to include industrial, government, public use, and transportation development in Southern California alone would have the potential to yield an additional 75,000 af of water savings per year by 2030, with corresponding reductions in energy use and carbon dioxide emissions. Finally, opportunities to implement LID practices that infiltrate or capture stormwater exist statewide. Even greater overall water supply, energy use, and GHG emissions reductions benefits would result from full application of LID and other green infrastructure techniques throughout all of California.

The Natural Resources Defense Council and University of California, Santa Barbara, research demonstrates that LID offers important opportunities to address vital issues of water quality and quantity, while simultaneously addressing climate change and its impacts on California. The results from this analysis suggest that LID is a worthy investment to meet many of the challenges faced by local agencies and communities.

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Chapter 22. Ecosystem Restoration

Ecosystem restoration improves the condition of California's modified natural landscapes and biological communities to provide for their sustainability and for their use and enjoyment by current and future generations. Few, if any, of California's ecosystems can be fully restored to their pre-development condition. Instead, efforts focus on rehabilitation of important elements of ecosystem structure and function. Successful restoration increases the diversity of native species and biological communities and the abundance of habitats and connections between them. This can include reproducing natural flows in streams and rivers, curtailing the discharge of waste and toxic contaminants into water bodies, controlling non-native invasive plant and animal species, removing barriers to fish migration in rivers and streams, and recovering wetlands so that they can store floodwater, recharge aquifers, filter pollutants, and provide habitat.

Overview

This strategy focuses on restoration of aquatic, riparian, and floodplain ecosystems because they are the natural systems most directly affected by water and flood management actions, and are particularly vulnerable to the impacts of climate change. Today, water and flood planning must prevent ecosystem damage and reduce long-term maintenance costs. Future water and flood management projects that fail to protect and restore their ecosystems will face reduced effectiveness, sustainability, and public support.

Restoration generally emphasizes recovery of at-risk species and natural communities, usually those whose abundance and geographic range have greatly diminished. These include several fishes, such as delta smelt, longfin smelt, green sturgeon, Chinook and coho salmon, and steelhead rainbow trout. Also included are riparian and wetland habitats and their member species, including valley elderberry longhorn beetle, giant gartersnake, and several migratory bird species. Successful restoration of aquatic, riparian, and floodplain species and communities ordinarily depends upon at least partial restoration of the physical processes that are driven by water. These processes include the flooding of floodplains, the natural patterns of erosion and deposition of sediment, the balance between infiltrated water and runoff, and substantial seasonal variation in stream flow. Another barrier to ecosystem restoration — displacement of native species by exotics — often results from the diminution of these same physical processes.

As an example, nearly all California waterways are controlled to reduce the natural seasonal variation in flow. Larger rivers are impounded to capture water from winter runoff and spring snowmelt and release it in the dry season. Many naturally intermittent streams have become perennial, often from receipt of urban wastewater discharges or from use as supply and drainage conveyances for irrigation water. The Sacramento-San Joaquin Delta (Delta) has become more like a year-round freshwater lake than the seasonally brackish estuary it once was. In each case, native species have declined or disappeared. Exotic species have become prevalent, often because they are better able to use the greater or more stable summer moisture and flow levels than the drought-adapted natives are.

Current Activities

Many important recovery efforts that affect water and flood management occur throughout California and are performed by public agencies, private agencies, non-profits, volunteers, or a combination of all the above. Some examples appear below.

The first example of recovery and restoration planning is in the Delta, where several efforts are under way. Water users are seeking to secure long-term assurances for Delta exports by formulating a Bay Delta Conservation Plan (BDCP). BDCP will identify how to improve the design and operation of the State and federal water projects and restore and manage habitats in the Delta. Once adopted, the BDCP will be implemented over the next 50 years. The schedule for release of the draft EIR/EIS is summer, 2012. The Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act) established a Delta Stewardship Council to develop a Delta Plan. State and local agency actions related to the Delta must be consistent with the Plan. The Delta Reform Act also required the State Water Resources Control Board (SWRCB) to develop flow criteria for the Delta ecosystem. The Board approved a staff report on development of flow criteria in August 2010 and submitted it to the Delta Stewardship Council.

Another example of restoration planning is the Central Valley Project Improvement Act (CVPIA) of 1992, which mandates changes in the management of the Central Valley Project, particularly for the protection, restoration, and enhancement of fish and wildlife. One component of the CVPIA is the Anadromous Fish Restoration Program (AFRP). The AFRP has a goal of at least doubling the natural production of anadromous fish in Central Valley streams. AFRP has helped implement nearly 200 projects to restore natural anadromous fish production.

A third example is the Central Valley Joint Venture (CVJV), which protects, restores, and enhances wetlands and associated habitats for waterfowl, shorebirds, and songbirds in the Central Valley through partnerships among conservation organizations, government agencies, and private landowners. The CVJV Implementation Plan focuses on wetlands and the values they provide to birds. It contains Central Valley-wide objectives, expressed as acres of habitat of seasonal and semi-permanent wetlands, riparian areas, rice cropland, and other waterfowl-friendly agricultural crops.

Fourth, the Southern California Wetlands Recovery Project, chaired by the California Natural Resources Agency and supported by the Coastal Conservancy, works to acquire and restore wetlands, watersheds, and streams in coastal Southern California. The aim is to reestablish a mosaic of fully functioning wetlands with a diversity of habitat types and connections to uplands to preserve self-sustaining populations of species. About 120 projects are in-process or are completed, with more than 2,700 acres acquired and protected and more than 800 acres enhanced or restored. These include Tijuana Estuary, South San Diego Bay National Wildlife Refuge, the Bolsa Chica and Ballona wetlands, and the Santa Clara River Parkway.

The final example is the Santa Ana River Watershed Program that successfully integrates habitat restoration and endangered species recovery with flood control, groundwater recharge, and water quality improvement. Prado Dam is a key component, serving both flood protection and water storage. There is a habitat area upstream of the dam that has expanded over the last 20 years to support both the largest patch of riparian forest and the largest number of the endangered Bell’s vireo (a songbird) in Southern California. The invasive giant reed (arundo) displaces native vegetation along the river, impedes flow during floods, and is a heavy water user. An aggressive program of giant reed removal serves to improve habitat for the vireo, reduce flood risk, and recover more water. The river is the main source of recharge for the Orange County Groundwater basin and consists mainly of treated wastewater from upstream cities. Constructed wetlands remove nitrogen from river water.

Potential Benefits

Provision of Ecosystem Services

California rivers and their associated floodplain ecosystems provide numerous public and private benefits that can be thought of as goods and services. These include water purification, groundwater recharge, erosion control, storage of floodwaters, hydropower generation, soil-building, pollination, wood products, carbon sequestration (greenhouse gas mitigation), fisheries, wildlife, and recreation.

Market opportunities for nature's services, often called "payments for ecosystem services", are contracts negotiated with landowners to manage land and water so as to maintain or enhance the specified services. A new direction in efforts to protect and restore ecosystems is to develop those markets. Numerous pilot projects are under way in California and elsewhere. These typically involve collaboration among diverse interests, agreement on a geographic boundary, identification of management practices, and – often the hardest step – economic valuation of the benefits derived from the practices. The projects also must identify beneficiaries and establish mechanisms for them to pay for the goods and services they receive.

Estimation of the monetary value of nature's services can be important information for resource managers who normally see only the costs of ecosystem protection, but not the benefits, in their budgets. Examples of current and emerging projects appear in Volume 2, *Regional Reports*, and include the following: farming for carbon capture and land subsidence reversal on islands in the Delta; forest, water, and fire management in the Mokelumne River watershed; mountain meadow improvement in the Sierra and Cascades; and natural resource management in the Santa Ana River watershed.

A recent initiative by the California Department of Conservation and the Environmental Defense Fund (the "Conservation Pivot") assesses the policy framework that supports conservation on farms and ranches. It concludes that broader use of economic incentives to measure and produce ecosystem services on privately owned lands is the key, both to protecting farms and ranches and to preserving and enhancing nature's services, in the face of population growth, infrastructure demands, and climate change.

Reliability of Water Supply

As ecosystem restoration actions help recover the abundance of endangered species, fewer Endangered Species Act conflicts should occur, particularly in the Delta. These conflicts repeatedly disrupt water supplies. Thus, one result of ecosystem restoration should be a more reliable water supply.

An example of a more direct water supply benefit is the restoration of meadows that occur in the headwaters of rivers and streams. Meadows have wide, shallow vegetated channels that spread flood peaks across the meadow floodplain and recharge the underlying aquifer. In contrast, gully erosion drains groundwater stored in meadows and eliminates meadow wetlands. Meadow restoration reverses gully erosion and returns the vegetation to wetland and riparian forms. The U.S. Forest Service estimates that meadow restoration in national forests in the Sierra Nevada could add 50,000 to 500,000 acre-feet of groundwater storage per year. See Chapter 23, "Forest Management," in this volume for further discussion.

Water Quality

The numerous ways that natural ecosystems contribute to water quality improvement are described in other resource management strategies in this volume. For the role of wetlands and riparian forests in filtering contaminants from runoff, see Chapter 18, “Pollution Prevention,” and Chapter 23, “Forest Management.” Chapter 23 describes the role of forests in preventing erosion and subsequent sedimentation of streams. Finally, Chapter 27, “Watershed Management,” explains that drinking water drawn from forested land requires less treatment than water derived from agricultural or developed land because it is less contaminated.

Sustainability

Water and flood management projects that incorporate ecosystem restoration are likely to be more sustainable than those that do not. Projects are more sustainable (that is, they operate as desired with less maintenance effort) when they work with, rather than against, natural processes that distribute water and sediment. Including ecosystem restoration in a project usually requires a degree of return to more natural patterns of erosion, sedimentation, flooding, and instream flow, among others. This, in turn, makes such projects more resistant to disruption by the natural processes, which makes these projects easier to maintain. As expected, cost savings over the life cycle of the projects accrues as a benefit, because repair and maintenance will cost much less.

Climate Change Mitigation and Adaptation

Ecosystem restoration can play a large role in climate change mitigation. Because plant growth depends on the capture and incorporation of atmospheric carbon into plant tissue, trees and other plants sequester carbon. Growth rates of trees in low-elevation riparian forests in California are among the highest in the world, outside except the tropics. Thus, significant expansion of riparian forest acreage in inland and coastal valleys could serve as a large carbon sink that offsets carbon emissions. Although construction activities during restoration could produce some greenhouse gases, those emissions should be far less than the total of greenhouse gases sequestered through forest growth.

Ecosystem restoration can also play a role in climate change adaptation. The Central Valley Flood Protection Plan outlines the State’s proposed response to a predicted climate regime of more frequent and larger floods. Part of that response is to increase the use of floodwater bypasses by creating new ones and widening the existing set. Beyond their role in flood protection, bypasses return floodplains to a more natural function and allow restoration of native floodplain vegetation. In turn, this helps to stabilize soils, increase groundwater infiltration and storage, and reduce floodwater velocities, bank erosion, and sedimentation of streams. Furthermore, because a return to a more natural floodplain function makes more room for flood peaks in valley areas, it allows more reservoir capacity to be dedicated to water supply, rather than be set aside for floodwater storage.

The expected shift to more severe flooding may diminish the ability to continue to farm many areas because the increased cost of recovery from floods could make farming uneconomical. However, making a clear dedication of land to expand flood-carrying capacity will reduce the flood risk on the remaining farmland and thus make that land more secure for agriculture.

Flood Management

The principal opportunities for improvement in both flood and habitat management occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. As suggested above, many actions taken for ecosystem restoration can also support more sustainable flood management.

Four major structural elements of flood management in California affect ecosystems: dams, levees, floodwater bypasses, and setback levees. Their flood management roles are clear. Dams impound floodwater and reduce peak flows. Levees keep rivers in their channels and off their floodplains. Bypasses allow controlled conveyance of floodwater across floodplains. Setback levees reduce water velocities and flood elevations, when compared to on-channel levees, and therefore sustain less erosion damage.

The combined use of dams and levees reduces the frequency and extent of floodplain inundation. In contrast, setback levees and bypass channels allow more frequent inundation of potential habitat space on floodplains. Native riparian and aquatic animal and plant communities of California are adapted to seasonal flooding conditions. Thus, setback levees and bypasses are better tools to integrate habitat and flood protection than dams and on-channel levees. Flood bypasses, in particular, can serve as important fish rearing habitat, which is a use of the Yolo Bypass today. The Yolo Bypass provides juvenile salmon with far better growth and survival opportunities than do the nearby channelized rivers that are now their main habitat.

Ecosystem restoration can improve flood protection by reducing levee erosion, increasing floodwater conveyance, deflecting dangerous flows away from levees, and strengthening levee surfaces. For example, levee erosion is a maintenance concern that often can be alleviated by slowing water velocity along the levee face. This can be done by setting the levee back and by growing plants on the lower levee slope and between the levee and the main channel. The vegetation reduces the force of water against the levee. Also, a new setback levee can be built with sound materials on a more stable foundation than many existing levees. The selection of appropriate vegetation is a key to reducing levee erosion while retaining the flood-carrying capacity of the stream channel.

A recent example of the use of suitable plants occurred at O'Connor Lakes on the Feather River, downstream of Yuba City, where a right-angle bend in the levee had been subject to severe and repeated erosion. A technical analysis of the paths taken by floodwater identified areas of the river channel where forest could remain (instead of being cleared periodically), areas where restoration of native trees and shrubs would not interfere with flood flows, and areas where the vegetation needed to be low and flexible enough to smooth the way for floods. The latter area was planted with native grasses and herbs. Overall, the new design increased the area of native vegetation by 230 acres, protected existing habitat from removal, reduced the risk of levee erosion and the need for expensive levee repair, and reduced the cost of keeping the channel clear for floodwater conveyance. Thus, a cheaper and more effective way to maintain the flood channel was also better for fish and wildlife habitat.

As with floodwater bypasses, habitat for juvenile fishes can be developed with setback levees. One such project on the lower Bear River in Sutter County was contoured to drain water and fish back to the river when floodwaters recede, thus preventing fish stranding. The project also created several hundred acres of

The second example results from the continued rise in sea level and upstream encroachment of salt water. As this happens, the brackish and fresh aquatic habitats of the Sacramento-San Joaquin Estuary, which are critical to many at-risk species, will shift upstream and inland. Continuing urbanization on the edges of the Delta will limit opportunities to acquire or restore lands that could provide suitable habitat. Thus, threatened and endangered species could be increasingly squeezed between the inland sea and the encroaching cities.

Conflicting Objectives with Traditional Flood Management

Ecosystem restoration and traditional flood management often have conflicting objectives. Traditional flood planning assigns all the physical space in a river channel to floodwater conveyance and leaves little room for habitat values. Many of the greatest opportunities for ecosystem restoration, especially in the Central Valley and other valleys, require incorporation of habitat into the flood protection system. At this early stage in statewide flood planning, there is a lack of consensus on how to design such an integrated system and on the desirability thereof. For example, many would balk at using newly-created flood capacity in a river channel to make room for forests.

Californians need to be satisfied that the promise of an integrated approach to flood and ecosystem management can provide habitat without greater risk of flood damage. A habitat project that fails to achieve its objectives is costly, but not dangerous. In contrast, a flood protection project that fails can mean catastrophe for life and property.

Opposition to Conversion of Farmland to Habitat

Many of the opportunities for ecosystem restoration are on land that is now farmed, especially in the Central Valley and the Delta. Although some habitat types, such as seasonal wetlands, can be farmed at other times of year, others, such as riparian forest and most permanent wetlands, cannot. Thus, significant amounts of habitat restoration on arable land, coupled with continued urban growth, could hasten the decline of some forms of agriculture in California. The loss of farmland, especially for habitat uses, is controversial.

Instream Flows

Restoration of adequate instream flows and channel and floodplain form and function is a priority for the California Department of Fish and Wildlife (DWF). DFW has legal mandates to determine flows that will ensure the viability of fish and wildlife, identify the watercourses to evaluate, initiate flow studies, and develop and submit recommendations to the SWRCB for use in allocating water. Much work remains to complete studies and develop recommendations. Until then, incomplete knowledge will hamper restoration of adequate stream flows.

Mercury Contamination

Wetland restoration carries the potential for methylmercury contamination. Some seasonally and permanently flooded wetlands can convert elemental mercury to methylmercury. Methylmercury is highly toxic and can accumulate in natural food chains and in fish that people eat. Many areas targeted for habitat restoration, particularly in and near the Delta, are contaminated with mercury. Hence, wetland restoration in those areas could exacerbate methylmercury production. The SWRCB approved a basin plan amendment for the control of methylmercury and total mercury in the Delta in 2011. The regulation forest and grassland habitat. The new, larger more durable levee, set back from the erosive forces of the river, improved flood protection for the urban area behind it.

Potential Costs

A comprehensive statewide summary of the costs of ecosystem projects does not exist. However, as of 2011, the Ecosystem Restoration Program, now managed by California Department of Fish and Wildlife, had funded 579 projects, worth about $718 million. About half of that amount was spent for riparian habitat, fish screens and improvements to water and sediment quality.

Under the authority of the Central Valley Project Improvement Act, State and federal government spent about $630 million for fish and wildlife restoration since 1992 (U.S. Department of the Interior 2005).

The Central Valley Joint Venture has used a mix of public and private funds to accomplish its goals. Table 22-1 below (updated March 2011) illustrates the budgets and the acres of habitat conserved (Central Valley Joint Venture 2011).

PLACEHOLDER Table 22-1 Acres Conserved by Central Valley Joint Venture

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

As of 2010, the Southern California Wetlands Recovery Project has spent more than $450 million completing projects from Santa Barbara County to San Diego County (Southern California Wetlands Recovery Project 2010).

Major Implementation Issues

Climate Change

Climate change will likely make preservation and restoration of key habitats more difficult. Perhaps the most important reason for this is an expected decline in the availability of moisture. A combination of rising temperatures, more intense floods, a smaller snowpack, more frequent drought, and more frequent and intense wildfires will reduce both surface and groundwater storage as more water runs off or evaporates and less water infiltrates into the ground. These changes in temperature and moisture will force species and natural communities to move with their preferred temperature and moisture regimes — uphill, northward, and into cool canyons — until blocked by topographic or other barriers. The result is that many species and ecosystems will occupy ever smaller and more isolated patches of physical habitat. As their abundance declines, more species will risk extinction.

Two examples are especially relevant to water and flood management. First, in many low- and middle-elevation streams today, summer temperatures often approach the upper tolerance limits for salmon and trout; higher air and water temperatures will exacerbate this problem. As the timing of peak tributary runoff shifts toward winter, less of the winter flow is likely to be captured in reservoirs. This will leave less cold water for fish in spring and summer. Thus, climate change might require dedication of more water simply to maintain existing fish habitat, and plans to expand habitat will face stiffer competition from other demands on water.

requires wetland project proponents to take part in evaluations of practices to reduce methylmercury discharges and apply controls.

Recommendations

1. Devise climate change adaptations that benefit both ecosystems and water and flood management. The principal predicted effect of climate change on California ecosystems is that it will further fragment and shrink them. Thus, appropriate corrective actions should serve to reconnect and expand them. The overarching recommendation is to establish large biological reserve areas that connect or reconnect habitat patches. These proposed “landscape reserves” are discussed further in the biodiversity and habitat section of the California Natural Resources Agency’s Climate Adaptation Strategy (2009). More specific measures that can help ecosystems adapt to climate change are those that integrate ecosystem restoration into flood and water projects. The following measures were discussed above:
   A. Reconnect rivers to their historic floodplains as part of new flood management approaches.
   B. Increase the use of setback levees and floodwater bypasses.
   C. Expand lowland riparian forest acreage in the form of continuous corridors along watercourses.
   D. Set aside habitat in the Delta to compensate for habitat lost to sea level rise.
   E. Restore mountain meadows.
2. Promote multidisciplinary approaches to water and flood management. Conflicting objectives are commonplace in water and flood planning which makes it essential to foster broad participation and collaboration among the affected parties to generate a shared vision of water and flood management that incorporates multiple interests. One promising approach is to devise a system of payments for ecosystem services in which beneficiaries pay natural resource managers for practices that support and enhance the desired goods and services. Stakeholders must identify and agree on what the relevant goods and services, the beneficiaries, and the monetary value of the benefits are.
3. Expand financial incentives for farmers to grow and manage habitat. Programs such as the Environmental Quality Incentives Program administered by the USDA, Natural Resources Conservation Service (NRCS) and DWR’s Flood Corridor grant program are examples of the direction that expansion could take. See Chapter 21, “Agricultural Land Stewardship,” in this volume for further discussion.
4. Provide for instream flow needs. Provide a comprehensive and appropriately funded program to identify instream flow needs, perform the necessary studies, and make scientifically defensible recommendations for instream flows to protect fish and wildlife.
5. Continue collaboration between wetland stakeholders and Regional Water Quality Control Boards (RWQCBs) to reduce mercury contamination. Wetland stakeholders are working with the RWQCBs to identify and conduct research to reduce human and ecosystem exposure to mercury without preventing other efforts to improve ecosystem health through wetland restoration.

Ecosystem Restoration in the Water Plan

[This is a new heading for *California Water Plan Update 2013* (Update 2013). If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy is not discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 22-1 Acres Conserved by Central Valley Joint Venture

NAWCA	Acres Conserved[a]	NAWCA Grant Funding	Federal Funding[b]	Non-Federal Partners[c]
All of California	714,000	$72,000,000	$109,000,000	$230,000,000
North Central Valley/Delta	341,400	$32,300,000	$82,000,000	$85,200,000
Southern Central Valley	258,600	$21,000,000	$21,700,000	$56,600,000

Notes:

[a] Reflects habitat protected, restored, and enhanced.

[b] This column reflects additional Federal partner contributions.

[c] This column reflects non-federal partner contributions.

Chapter 27. Watershed Management — Table of Contents

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Chapter 27. Watershed Management

Watershed management is the process of creating and implementing plans, programs, projects, and activities to restore, sustain, and enhance watershed functions. These functions provide the goods, services, and values desired by the human community that are affected by conditions within a watershed. In California, the practice of community-based watershed management, which is practiced in hundreds of watersheds throughout the state, has evolved as an effective approach to natural resource management. These community-based efforts are carried out with the active support, assistance, and participation of several State agencies and programs.

Managing at a watershed level has proven to be an appropriate organizing landscape unit for the coordination and integrated management of the numerous physical, chemical, and biological processes that make up a river basin ecosystem (Box 27-1). A watershed serves well as a common reference unit for the many different policies, actions, and processes that affect the system, and it also provides a basis for greater integration and collaboration among those policies and actions.

PLACEHOLDER Box 27-1 Watershed Defined

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Watershed Management in California

A primary objective of watershed management is to increase and sustain a watershed's ability to provide for the diverse needs of the communities that depend on it, including local, regional, State, federal, and tribal stakeholders. Significant efforts to better manage natural resources using a watershed approach are occurring in several hundred structured efforts in all regions of California, involving organizations, local governments, landowners/users, and stewardship groups along with State and federal agencies.

Many of these efforts are working to blend community goals and interests with the broader goals of the State as a whole in a manner consistent with improving environmental, social, institutional, and economic conditions within the watershed. The need to address environmental justice and social equity has been recognized and addressed, along with more traditional project management approaches.

In many communities, these organized efforts serve as forums to bring about collaborative management involving the public and private sector; the academic community; and people working at the local, regional, State, and national levels, all benefitting from the inherent capabilities of each group. The benefits of watershed-based management are being realized in such diverse locations as the upper Feather River, the Los Angeles River basin, and the Napa River.

In addition to these local efforts, a number of regional, statewide, and national initiatives have been carried out to help improve the overall ability to practice watershed management. A chronology of some notable initiatives in California can be found in *California Water Plan Update 2009*, Volume 2, Chapter 27, available online at http://www.waterplan.water.ca.gov/cwpu2009/index.cfm (California Department of Water Resources 2009).

Bond measures have brought significant funding for the maintenance and restoration work that is needed in many of California's watersheds. Proposition 50 (2002) and Proposition 84 (2006) stressed the need for integrated planning that includes objectives at the watershed and regional scales, and provide incentives to carry out work consistent with these plans.

Potential Benefits

Managing people's interactions with and impacts on natural ecosystems using a watershed approach that emphasizes maintaining, restoring, or enhancing the many functions associated with these natural systems produces a number of significant benefits. Many of the benefits (such as reliable quantities of clean water, agricultural or forest products, and biofuels) or avoided costs (such as reduced flood or fire damages) can be described using traditional economic terms, such as products, goods, or services, and are readily quantified and valued in the traditional marketplace. Other values associated with natural systems such as biological diversity, disease suppression, and climate moderation are more difficult to quantify monetarily because these values are not routinely traded in the marketplace. As a result, the term "ecosystem services" is often used to better describe and equate the monetary and non-monetary values or benefits provided to society by healthy watersheds. Some typical watershed products, goods, and services are listed in Table 27-1.

PLACEHOLDER Table 27-1 Typical List of Watershed Products, Goods, and Services

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Potential Costs

Costs associated with watershed management depend on many factors, such as the size of the watershed; the land and water use activities occurring in the watershed; the condition and trends of the watershed; and the values, goods, and services demanded from the watershed. Much of the cost of watershed management in California is associated with the specific land or water use activities occurring within the watershed on a recurring basis and is directly related to these uses. The additional or external costs of watershed management that are discussed in this chapter tend to be associated with interventions designed to influence management or improve the results of management, to offer specific protection for certain functions and values, or to restore the functional conditions and associated uses of a watershed. These interventions may come from various levels of government or interests either within or outside the watershed. A methodological approach is used for estimating costs associated with specific watershed-scale resource management efforts. Using this approach, the potential costs associated with these interventions are estimated by:

- Extrapolating costs based on available estimates of other program expenditures (see Table 27-2, used in *California Water Plan Update 2005* and *California Water Plan Update 2009*, in resource management strategy chapters on watershed management). Estimates are based on CALFED watershed management estimates scaled up for statewide coverage.
- Applying a "willingness to pay" approach based on existing examples (using CALFED Watershed Program analysis as part of program finance plan development).

In addition to the more easily quantified benefits of well-functioning watersheds, effective watershed management can also result in significant avoided costs, such as lessened fire and flood damage, erosion and sediment loss reduction, water quality maintenance, reduced illnesses and treatment costs, and control of agricultural pests. An example is shown in Box 27-2, "Watershed Degradation and Water Treatment Costs."

PLACEHOLDER Table 27-2 Estimates of Watershed Management Costs to Year 2030

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

PLACEHOLDER Box 27-2 Watershed Degradation and Water Treatment Costs

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Willingness to Pay

To estimate the approximate external costs to fully implement the watershed management strategy, an analysis developed by the CALFED Watershed Program was used, which examined areas where communities have chosen to provide quantifiable financial support for watershed management, thus demonstrating "a willingness to pay" for the services provided by a well-managed watershed. This analysis, developed using methods described by the U.S. Department of Energy (Ulibarri and Wellman 1997) and the U.S. Congressional Research Service (Breedlove 1999), is an attempt to assign a monetary value to effective watershed management.

Napa County was used as a basis for this comparison for several reasons. First, it has a demographic similarity to the demographic makeup of the state as a whole. Second, taxes are collected that are directly tied to implementation of community-generated watershed management plans; these tax levies also demonstrate strong local support among voters and elected officials for the values inherent in improved watershed management. Finally, these funds are generated and dispersed locally, by locally responsive government entities.

Valuations from three different Napa County tax measures were investigated:

- A half-cent sales tax passed by 68 percent of voters in the late 1990s that generates approximately $10 million in revenue per year specifically for watershed management (the "Living River" program).
- A parcel tax of $12.70 per parcel that is supported and levied within the city of Napa for watershed management.
- An additional parcel tax of $12 per year specifically for stormwater runoff management inside the city's watersheds.

These assessments generate funds (based on 2009 estimates) that range from nearly $14,000 per square mile for the sales tax revenue, to just less than $1,600 per square mile for the parcel tax. For the purposes of this value estimate, a lower amount of $1,572 per square mile is used, which in turn is adjusted to account for the slight difference in demographic statistics between Napa and California at large. These value estimates (Table 27-3) represent the annual, external cost of fully implementing the watershed management strategy over approximately half the surface area of California, including all or part of the Sacramento River, San Joaquin River, Tulare Lake, San Francisco Bay, South Coast, and South Lahontan hydrologic regions.

PLACEHOLDER Table 27-3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Simple extrapolation of this value to the entire land area of the state would result in an estimated annual cost of $221 million to fully implement the strategy. For this example, "fully implement" suggests extensive application within the regions of the policy-level and strategic practice recommendations in this chapter. It should be noted here that an as-yet-undetermined, but likely significant, portion of that cost is not an added cost, but existing expenditures applied differently. For instance, permits and stream alteration agreements issued by watershed boundary instead of jurisdictional boundary could result in considerable added benefit and positive effect without adding to the real cost of implementation. Also, land use planning done on the basis of watershed impact may yield higher beneficial results without increasing costs.

Major Implementation Issues

Managing land and water resources for selected products, services, and values has altered the conditions and functions of many watersheds in California. These management activities have produced some negative effects that need to be addressed to continue to effectively manage and utilize watershed services.

Altered Hydrologic Cycles

The hydrologic cycle includes precipitation, flow of water over the land and under ground, and evaporation into the atmosphere. How land is managed can reduce rainwater infiltration and the timing and volume of runoff. Storms are increasingly characterized by high-intensity runoff over short periods, especially in urban areas but also in some rural areas, which creates a risk of flooding and reduces the ability of the water supply infrastructure to capture water for use during dry times. This compression of runoffs robs the streams and landscape of groundwater, leading to dry land, a shift in vegetation types, lower and warmer streams, and deterioration of stream channels, all of which lead to shifts in the plants and wildlife that can be supported. In some areas, diversion of water from streams in the watershed to other regions outside the watershed, or application of water imported from outside the watershed, has dramatically changed ecological functions or altered the flow of water through the watershed.

Altered Nutrient Cycles

As watersheds are developed, the amount of dissolved nutrients in streams within the watershed is increased, often from fertilizers or biosolids. These increased concentrations of nutrients can trigger dramatic changes in water bodies, vegetation, and wildlife communities. Nutrients generated by human activity are frequently exported from the location where they are generated or applied by humans to a downstream or downslope water body, often from inappropriate use or excessive application rates, where they can support algae or other plant growth that impairs the usability and ecological quality of water bodies. In addition to direct effects on surface waters and groundwater, increased nutrients can lead to the establishment of non-native invasive plant species at the expense of native vegetation. Many native plants evolved under relatively low nutrient conditions, and increased nutrient availability often creates conditions that favor non-native invasive plant species, which can outcompete the native vegetation and form stands of a single species with little or no biological diversity, little habitat value for wildlife, and altered soil conditions such as reduced infiltration capacity.

Life Cycles and Migration Patterns of Wildlife

Many projects built in the past, prior to modern environmental laws such as the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), have disrupted wildlife migration corridors or destroyed or degraded habitat that is critical for certain animal life stages. Some examples of the effects of watershed alteration on wildlife ecology are found in the changes in freshwater inflows to coastal wetlands caused by changed watershed conditions, which directly affect many estuarine and ocean species that breed and rear in these communities; blocked access to spawning and rearing habitats for anadromous fish by the dams that impound water on most significant California waterways; and reduction in extent of the riparian forests that support migration of Pacific Flyway bird species.

Fire and Water

Active suppression of wildland fires since the 1920s has created an increased risk of larger, more intense wildfires that do much more damage to watersheds than fires of historical intensities. Modern watersheds have limited capabilities of rapidly recovering from these fires, and accelerated soil erosion, diminished productivity and diversity of plant communities, displaced wildlife, significant alterations of natural biological cycles, and limited subsequent human use of the lands are typical aftereffects. Catastrophic fires also have large effects on hydrology and water quality within a watershed, causing increased surface runoff and reduced infiltration, creating more frequent and severe downstream flood events, exacerbating water quality problems, increasing operation and maintenance costs for reservoirs and canal systems, and producing large economic losses to local communities.

Climate Change

Watershed integrity is vulnerable to the changes in temperature, precipitation, and water flows that are likely under currently projected scenarios of climate change. As indicated in Box 27-1, each element of a watershed system must be considered in context with the others because changes in one element (e.g., the hydrologic cycle) spur changes in the others (e.g., the roles of flood and fire), creating a different system outcome. Watersheds within regions where precipitation decreases can become more susceptible to pests, fires, and pollutants. Projected increases in storm intensity could increase inland and coastal flooding, increasing the likelihood of downstream property damage and loss of life, and runoff from high-intensity storms would cause increased rates of soil erosion and soil loss, particularly in watersheds recovering from recent droughts and fires, because soils in those areas will lack vegetation cover that stabilizes soils.

Adaptation

As indicated in Table 27-1, a diverse watershed ecosystem can be resilient to changes in climate, so maintaining healthy watershed ecosystems will be of critical importance in the face of a changing climate by ensuring that ecosystem functions within a watershed will continue to provide the goods, services, and values of the systems we rely on today. How land is managed affects the way watersheds can adapt to the effects of climate change, and an effective watershed management strategy provides multiple benefits to human society, such as producing water, food, fiber, and fuel; mitigating floods and droughts; providing aquatic and terrestrial habitats and recreational opportunities; moderating local climates; and maintaining biodiversity and healthy soils. Managing interactions with natural watershed systems to maintain, restore, and enhance the many functions within a watershed allows Californians to have reliable quantities of clean water, as well as agricultural and forest products. An effective watershed management strategy also helps to reduce the cost of flood and fire damages, suppress disease, and increase biodiversity.

Mitigation

California's forested watershed ecosystems have relatively high carbon sequestration potential, and appropriate vegetation management can significantly increase rates of carbon sequestration as well as reduce rates of natural greenhouse gas (GHG) emissions. Improved watershed management for water reuse, pollution control, and other ecosystem services could provide multiple opportunities to reduce the energy use and emissions of GHGs. Tracking and reporting changes in California's major watersheds could help to assess and evaluate water quality and watershed conditions for controlling pollution and saving related energy.

Supporting adaptive management programs could provide opportunities to control energy use and GHG emissions by avoiding negative impacts on ecological conditions, water quality, and watershed functions; and adjusting the operations or redesigning existing projects to create benefits for climate change mitigation. Providing technical information and watershed education and outreach in the decision-making process could have long-term benefits for climate change mitigation related to the maintenance and improvement of watershed functions, water conservation, water reuse, and water pollution prevention.

Other opportunities within this strategy to mitigate for energy use and GHG emissions include management actions to maintain and improve watershed function, such as: designing and selecting projects to avoid negative impacts on ecological conditions, water quality, and watershed functions; and controlling stormwater, reducing surface runoff, and retaining intact floodplains and wetlands to maintain and improve watershed function and control water pollution.

Water use efficiency practices in watersheds could have benefits for reducing energy use and GHG emissions. These include decreasing the amount of irrigated landscaping in the watershed and increasing the use of native vegetation in landscaping and agricultural buffer lands; and installing and maintaining stream flow gauges to measure water use. Improving watershed ecosystem functions by restoring and preserving stream channel morphology and creating habitats around stream and river corridors could provide carbon sequestration potential for GHG reduction. However, energy use efficiency and clean energy standards should be used to offset related GHG emissions during restoration.

Links to other Resource Management Strategies

Watershed management is linked to the following resource management strategy chapters within this volume:

- Chapter 4, "Flood Management."
- Chapter 15, "Drinking Water Treatment and Distribution."
- Chapter 18, "Pollution Prevention."
- Chapter 19, "Salt and Salinity Management."
- Chapter 20, "Urban Stormwater Runoff Management."
- Chapter 21, "Agricultural Land Stewardship."
- Chapter 22, "Ecosystem Restoration."
- Chapter 23, "Forest Management."

- Chapter 24, “Land Use Planning and Management.”
- Chapter 25, “Recharge Area Protection
- Chapter 29, “Outreach and Engagement.”

PLACEHOLDER Box 27-3 High Sierra Snow Fence Application: an Innovative Tool for Watershed Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Recommendations

Policy-Level Recommendations

1. Establish a scientifically valid means of tracking and reporting changes in the state’s major watersheds that provide reliable, current information to local communities, State and federal agencies, and others, regarding the net effects of management against the background of external change.
2. Support adaptive management programs that regularly assess the performance and condition of projects and programs to determine if they are satisfying ecological and community needs compatibly. Adjust the operations or redesign existing projects or programs as needed.
3. Clearly define expected products, goods, and services at the State level, to provide a large-scale basis from which to apply local variations and additions.
4. As appropriate and feasible, coordinate State funding and support within watersheds and between programs to generate more focused, measurable results.
5. More effectively align agency goals and methods to reflect coordinated approaches to resource management using watersheds as the unit of implementation and effectiveness measurement.
6. Provide easy access to technical information such as geographic information system layers, monitoring data, planning models and templates, and assessment techniques from multiple sources, which are useful at multiple levels of decision-making.
7. Conduct management activities in a manner, and within a context, that is consistent with watershed dynamics and characteristics.
8. Provide local land-use decision-makers with watershed education and information access to promote maintenance and improvement of watershed functions in local decision-making.

Strategic Practice Recommendations

1. Use a watershed approach to coordinate forest management, land use, agricultural land stewardship, integrated resources planning, and other appropriate resource strategies and actions.
2. Design and select projects with ecological processes in mind and with a goal of making the projects as representative of the local ecology as possible.
3. Increase precipitation infiltration into the soil to reduce surface runoff to a level that is typical of natural runoff retention patterns. This goal is often achieved by reducing impervious surfaces within a watershed. Retain intact floodplain and other wetlands to the extent possible, to maintain or increase residence time of water in the watershed.
4. Decrease the amount of irrigated landscaping in the watershed and increase the use of native vegetation in landscaping and agricultural buffer lands.

5. Design appropriate wildlife migration corridors and biological diversity support patches within watersheds when planning fire-safe vegetation alteration.
6. Promote the installation and maintenance of stream flow gauges in major drainages.
7. Maintain and create habitat around stream and river corridors that is compatible with stream and river functions. Provide as much upslope compatibility with these corridors as possible.
8. Design drainage and stormwater runoff controls to maximize infiltration into local aquifers, and minimize immediate downstream discharges during runoff.
9. Provide regionally appropriate, regular, and dependable educational materials to encourage water conservation, water reuse, and water pollution prevention.
10. Restore and preserve stream channel morphology to provide floodwaters access to the floodplain and to encourage stable banks and channel form.
11. Restore the characteristics and functions of native grasslands, woodlands, forests, and other wildlands.
12. Remove or control invasive weeds as a part of overall resource management efforts.
13. Protect soil resources and restore the functions of drastically disturbed soils, to slow runoff and increase rainfall infiltration.
14. Proactively address the recovery of special-status species, at both watershed and population scales, and incorporate measures to avoid future listing of other at-risk species.

Watershed Management in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions aren’t consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn’t discussed in the rest of Update 2013), there is no need for this section to appear.]

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Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy.

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Table 27-1 Typical List of Watershed Products, Goods and Services

Typical watershed products, goods and services (also described as ecosystem services)	Benefit of service
Provision of water supplies	Agriculture, municipal, industrial, and other beneficial uses
Provision of food, fiber, fuel	Sustainable production of agricultural and forest products that are dependent on healthy productive soils, favorable climate and water conditions, and the availability of pollinators
Water purification/waste treatment	Well managed watersheds produce clean, cool water generally useful for a broad range of beneficial uses. Virtually all fresh water used in California originates as precipitation that is intercepted, captured, routed, and released from watersheds in California and the Colorado River Basin.
Flood mitigation	Healthy watersheds with adequate distributed wetlands and functional floodplains moderate the volume and timing of surface runoff reducing flood damage.
Drought mitigation/flow attenuation	A healthy watershed works like a sponge to store and release water to both streams and groundwater. In California, healthy watersheds increase the residence time of water, and tend to store and release water longer into the dry season.
Provision of aquatic and terrestrial habitat	Uplands, rivers, streams, floodplains, and wetlands provide necessary habitats for fish, birds, mammals, and countless other species, and generally sustain a strong level of biological diversity that provides wide benefits to society.
Soil fertility, health, productivity	Soil health and fertility is an essential component of primary ecosystem production, and is critical for maintenance of important terrestrial, floodplain, riparian, and wetland components and processes.
Nutrient, mineral cycling and delivery, carbon sequestration	Cycling of nutrients is necessary to maintain healthy, diverse biological systems, to sustain biological diversity that mediates disease, and to sustain populations of native species.
Biodiversity maintenance	Diverse assemblages of species work to provide the services (including all those listed in this table) upon which societies depend. Conserving genetic diversity preserves options for the future and increases the resilience of ecosystems in the face of the impacts of a changing climate.
Recreational opportunities	Swimming, fishing, hunting, boating, wildlife viewing, hiking, and skiing are all delivered or enhanced in healthy watersheds, often resulting in concurrent economic improvements in local communities reliant on recreation as a source of economic sustenance or growth.
Climate moderation/buffering	Generally, a diversified watershed ecological system is more robust and resilient to rapid climate changes or other types of disturbance. Maintaining a resilient watershed ecosystem will be of critical importance in the face of a changing climate. That adaptation will better ensure that watershed ecosystem functions will continue to provide the goods, services, and values of the systems we experience today.
Aesthetics	Quality of life is a major, but difficult to quantify, benefit of watershed conditions. Pleasant surroundings, with clean air, clean water, and adequate recreational opportunities have been shown to be beneficial across a broad spectrum of social structures.
Managing salinity gradients	Freshwater flow regimes can determine salinity gradients in deltas, coastal estuaries and near-shore marine environments, a key to biological richness and complexity.

Source: Table content adapted from *Rivers for Life: Managing Water for People and Nature* (2003) by Sandra Postel and Brian Richter.

Table 27-2 Estimates of Watershed Management Costs to Year 2030, from Water Plan Update 2005 and CALFED Program Estimates

Period (years)	Assessment-planning [a] ($ millions)	Public process [b] ($ millions)	Projects [c] ($ millions)	Total for period ($ millions)
2004-2009	$10-$37.5	$8-$16	$14-$80	$160-$667
2010-2015	$10-$30	$8-$16	$14-$88	$160-$804
2016-2030	$10-$25	$8-$16	$14-$100	$160-$2,115
Total				**$480-$3,586**

Source: *California Water Plan Update 2005,* Volume 2 Resource Management Strategies, Chapter 25, Watershed Management.

Note: The CALFED service area is defined as the Sacramento and San Joaquin River basins, the Tulare Lake Basin, The Delta and San Francisco Bay Area, and that portion of central and Southern California serviced by the State Water Project

[a] CALFED service area estimated as 40% of statewide need. Therefore, statewide assessment and planning = 2.5 x CALFED values from draft CALFED Finance Plan (2004)

[b] The service area for public process estimated as 25% of the statewide need. Therefore, statewide public process = 4x CALFED values

[c] For projects, CALFED service area is estimated to be 25% of the statewide need. Therefore, statewide projects = 4x CALFED values

Table 27-3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay

Napa County	Less 10%	Bay-Delta watershed area (mi^2)	Southern California area (mi^2)	Total value estimated
$1,572 per mi^2	$1,414 per mi^2	48,050		$67,942,700
			30,000	$42,420,000
Total Valuation:				**$110,362,700**

Source: California Department of Water Resources 2011

Box 27-1 Watershed Defined

What is a Watershed?

In its historical definition, a watershed is the divide between two drainage streams or rivers separating rainfall runoff into one or the other of the basins. In recent years, the term has been applied to mean the entirety of each of the basins, instead of just the divide between them. The Continental Divide is a watershed according to the earlier definition, where rainfall runoff is directed toward the Gulf of Mexico or toward the Pacific Ocean. The Mississippi River basin and the Colorado River basin are watersheds under the new definition. Other parts of the world use the terms catchment, or river basin, to describe the drainage area between (historical) watersheds. It is from the earlier definition of watershed that we derive the phrase "watershed event"—an occurrence that changes the pattern of all that follows, moving the flow of events toward a different outcome.

A watershed includes all natural and artificial (manmade) features, including its surface and subsurface features: climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. A watershed may be a small area or as large as the Sacramento, San Joaquin or Klamath River basins.

Using watersheds as organizing units for planning and implementation of natural resource management means that:

- Large regions can be divided along topographic lines that describe a natural system more accurately than typical jurisdictional lines.
- Condition and trends analysis can be done on the basis of the entire natural system, in concert with economic and social conditions.
- Communities, including resource management and regulatory agencies, within and outside a particular watershed can better track and understand the cumulative impacts of management activities on the watershed system.
- Managers within each watershed can more effectively adjust their measures and policies to meet management goals across scales, including regional and statewide goals.
- Multi-objective planning is facilitated by inclusion in, and reference to, a whole-system context.

Effective management recognizes the mutually dependent interaction of various basic elements of a watershed system including the hydrologic cycle, nutrient and carbon cycling, energy flows and transfer, soil and geologic characteristics, plant and animal ecology and the role of flood, fire and other large scale disturbance.

Each must be considered in context with the others, because change in one spurs changes in the others, creating a different system outcome.

Box 27-2 Watershed Degradation and Water Treatment Costs

The development of watershed and aquifer recharge lands results in increased contamination of drinking water. With increased contamination come increased treatment costs. The costs can be prevented with a greater emphasis on source protection. A study of 27 water suppliers conducted by the Trust for Public Land and the American Water Works Association in 2002 found that the more forest cover in a watershed, the lower the treatment costs. According to the study, "Approximately 50 to 55 percent of the variation in treatment costs can be explained by the percent of forest cover in the source area. For every 10 percent increase in forest cover in the source area, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover."

The study did not gather enough data on suppliers with over 65 percent forest cover to draw conclusions; however, it is suspected that treatment costs level out when forest cover is between 70 and 100 percent. The 50 percent variation in treatment costs that cannot be explained by the percent forest cover in the watershed is likely explained by varying treatment practices, the size of the facility (larger facilities realize economies of scale), the location and intensity of development and row crops in the watershed, and agricultural, urban, and forestry management practices. The table shows the change in treatment costs predicted by this analysis, and the average daily and annual cost of treatment if a supplier treats 22 million gallons per day.

Table A Change in Water Treatment Costs for Each 10% of Forest Cover in Source Watershed

Percent of watershed forested	Treatment and chemical costs per million gallons	Change in costs	Average treatment costs	
			Daily	Per year
10%	$115	19%	$2,530	$923,450
20%	$93	20%	$2,046	$746,790
30%	$73	21%	$1,606	$586,190
40%	$58	21%	$1,276	$465,740
50%	$46	21%	$1,012	$369,380
60%	$37	19%	$814	$297,110

Source: Extracted from Land Conservation and the Future of America's Drinking Water - Protecting the Source (2004). Published by the Trust for Public Lands and the American Water Works Association

Box 27-3 High Sierra Snow Fence Application: an Innovative Tool for Watershed Management

Overview

In coming years, mountain stream runoff is expected to result in higher flows over shorter durations, thereby causing earlier and greater spring flooding followed by a longer, dry summer period, which may affect sensitive environments. Snow fences have been used extensively by state transportation departments to reduce snow drifting over roadways. Local-scale strategic placement of properly designed snow fencing could also be used as an effective tool for water management to reduce the negative effects of warming, strengthen forest and watershed management, and facilitate slower snow melt to extend runoff into the summer. For example, the Sierra Nevada produces more than 50 percent of California's water, and snow fences could be used in some locations to accumulate larger volumes of snow mass and extend water delivery for supply and power generation. This may reduce water loss due to evaporation and sublimation, increase soil moisture retention, and enhance forest wildlife habitat. Details of a proposed pilot study on snow fences, application in neighboring states, preliminary cost estimates, and a work plan outline and schedule appear in *Catch the Drift: An Innovative Application of Snow Fencing Technology* (California Department of Water Resources 2012).

Snow Fence Concepts

To improve watershed management, snow fencing should be strategically placed in small openings (clear cuts or high elevation meadows) less than one-half hectare. Key positioning atop ridgelines adjacent to cliffs and ravines could also enhance snow mass accumulation. As shown below, when positioned perpendicular to the prevailing wind direction, snow fencing intercepts the wind to reduce snowflake velocity and create a snow sedimentation basin downwind of the fence.

PLACEHOLDER Figure A Snow Transport and Deposition Mechanism

[The draft figure follows the text of this box.]

PLACEHOLDER Photo A Living Snow Fence Depicted in Summer and Winter

[The draft photo follows the text of this box.]

Effective snow fences are 6-12 feet high. Snow mass collected behind the fence is distributed over a longitudinal area that can be up to 25 times the fence height. Manmade snow fences can be placed parallel to planted rows of trees that serve as a natural, living fence. After the trees mature, the manmade fence can be removed.

Benefits — Water Management

Snow fences can:

- Reduce spring runoff and extend snowmelt.
- Augment water supply.
- Support better local flood control.
- Help extend hydroelectric generation into summer.

Benefits — Social Impacts

Snow fences can:

- Strengthen public relations by suggesting realistic, simple, and economic solutions that could be implemented at the local level.
- Benefit tribal lands.
- Increase interagency water management collaboration.

Benefits — Environment and Habitat

Snow fences can:

- Accelerate ecosystem restoration.
- Improve habitat by decreasing sedimentation and erosion and increasing reforestation, meadow improvement, and forest sustainability.
- Enhance soil moisture retention.
- Augment streams with colder water in summer to benefit aquatic life by increasing dissolved oxygen levels.

Potential Challenges

Potential challenges to using snow fences as a tool:

- Unknown benefit-to-cost ratio in California.
- Permitting requirements.
- Sponsors and funding.
- Operations and maintenance.

Figure A Snow Transport and Deposition Mechanism

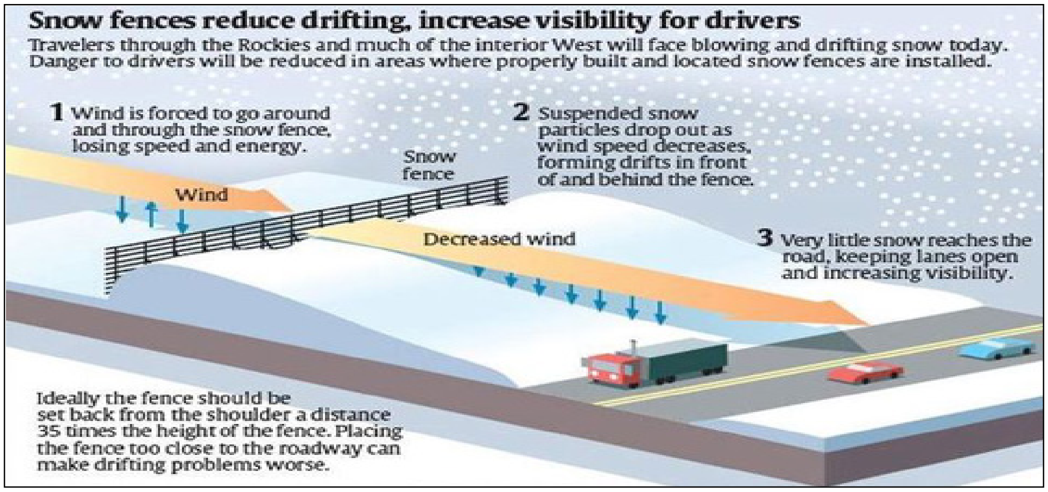

Photo A Living Snow Fence Depicted in Summer and Winter

[photo to come]